ADVENTURE ABOVE THE CLOUDS

BY

F. V. MONK

AND

H. T. WINTER

Member of the Royal Aeronautical Society

Authors of "Great Exploits in the Air"

With Eight Half-tone Plates and Diagrams

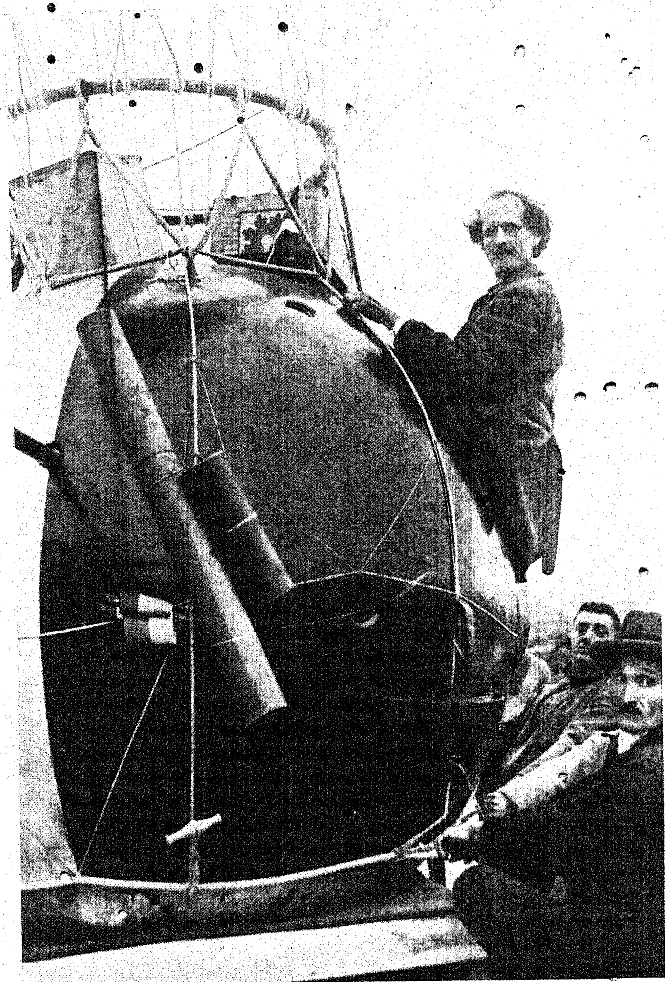
BLACKIE & SON LIMITED
LONDON AND GLASGOW

ADVENTURE ABOVE THE CLOUDS

BLACKIE & SON LIMITED
50 Old Bailey, LONDON
17 Stanhope Street, GLASGOW

BLACKIE & SON (INDIA) LIMITED
Warwick House, Fort Street, BOMBAY

BLACKIE & SON (CANADA) LIMITED
TORONTO



EXPLORING THE STRATOSPHERE

Professor Piccard about to enter the spherical "cabin" in which he made his second ascent, reaching a height of 54,450 feet (about 10⅓ miles)

Page 142 *Frontispiece*

Printed in Great Britain by Blackie & Son, Ltd., Glasgow

Contents

List of Illustrations

Bibliography

Pick: *Meteorology*.

Geddes: *Meteorology*.

Air Ministry: *Meteorological Glossary*.

Nayler and Ower: *Aviation of To-day*.

Glaisher: *Travels in the Air*.

Royal Meteorological Society: *Proceedings*.

Freeman: *Recent Advances in Physics*.

Lasser: *Conquest of Space*.

Vivian and Lockwood Marsh: *History of Aeronautics*.

Tissandier: *Travels*.

Royal Aeronautical Society: *Journal*.

" Flight ".

" The Aeroplane ".

Note

The Log of Professor Piccard, which appears in Chapter XIII, is published by the kind permission of *The Times*.

To
Charles Myers

ADVENTURE ABOVE THE CLOUDS

CHAPTER I

A Stirring Adventure

> " Higher still and higher,
> From the earth thou springest;
> Like a cloud of fire
> The deep blue thou wingest,
> And singing still dost soar, and soaring ever singest."
>
> —*Shelley*.

Death comes very close

A heavy gust of wind swept across the lawn and dashed the envelope of the balloon against the branches of the trees.

Now or never. The three adventurers hastily stepped into the car.

" Cut away there everywhere!"

The ropes holding down the craft were slashed through and the *Neptune* rushed upward, only just missing the trees and the lightning conductor on the building.

The departure was so swift and dangerous that the onlookers on the lawn held their breath and gazed upward with startled, straining eyes.

They saw the balloon reach a great height as if with a single bound, and then suddenly disappear.

The clouds had swallowed it up.

That was at half-past twelve of a September day in 1868, and at half-past four the *Neptune*, many miles away, was revolving and falling rapidly to earth.

The three balloonists looked anxiously over the side of the car. The earth seemed to be rising swiftly to strike them, and all their ballast had already been thrown out so that there was no way of checking the fall.

Down they went and there was an increasing rush of air in their ears. They were 1000 feet above the earth, then only 800 feet, then 600, 400, 200.

They let go the grapnel. It hit the ground and was pulled along over it, not being able to get a hold.

The anchor was dropped. That also ran swiftly over the plough land, catching now and again in the humps and ridges and nearly jerking the occupants of the car out over the side. There was going to be a terrific bump in

a minute or so and Tissandier hastily gathered together the scientific instruments and packed them up securely, whilst Fonvielle collected the odd bottles lying about. If there was to be a crash there must be no glass about to cut them.

A coppice of lofty trees loomed up before them. They were dashing straight for it, swept on by a tearing wind. Another heavy jolt sent Tissandier reeling into Duruof, and when they picked themselves up and saw the great trees rushing towards them they knew that they could not escape disaster.

The wind that swept them along at a furious pace was rocking the great branches and screeching through the tossing leaves. The valve-rope—quick, the valve-rope! But it was not in its place: it had become loose and was blowing out on the gale. Duruof climbed up the car side and at great risk reached out for it. It was tugged out of his hand again.

Then there was a sharp crack, another and another, and a loud shout from Captain Duruof: "The balloon's burst!"

The balloon had surely burst, and the torn envelope was fluttering and dancing a dance of death above the doomed ones.

Down they shot and hit the ground with a terrific shock, just as Tissandier leapt up into

the loop in a last wild effort to break the full force of the impact.

The whole structure collapsed and flattened out, and there was stillness save for the flapping of the fabric in the wind.

They were all dead—surely they must be dead?

Then the deep voice of Duruof sounded: "Come out of there, you fellows—come out!" The other two, Tissandier and Fonvielle, lying under the overturned car, heard the words as if from an immense distance and from a different world.

When the crash came Tissandier, who had jumped from the ring, felt all the wind knocked from his body, and both he and Fonvielle were suddenly plunged into a darkness as black as Avernus.

"We are blind," they told themselves, "and this is death." But as they lay there the cheery voice of their chief calling them to come out brought them back to full consciousness, and then they realized that as they were thrown to earth the car had come down upon them like a thimble over a couple of flies, and shut them in in complete darkness.

As peasants came running from distant fields, thinking to gather up the dead and wounded, Tissandier and Fonvielle got upon their knees,

and the car rose with them. There was Duruof with a rueful grin upon his face, and there, fleeing on the relentless blast, were the rags and tatters of their lovely *Neptune*.

Search for a Great Treasure

What was it they had been after, those three? For what had they soared up out of sight beyond the clouds in their frail craft, the *Neptune*? Was it a mad adventure just for the sake of adventure? Indeed it was not.

When at twelve-thirty they had shot up from the lawn of the Conservatoire des Arts, Paris, and gone out of sight behind the curtain of clouds, they were off on a great adventure, the greatest adventure of all, in fact, no less than the search, in strange realms, for a priceless treasure—a grain, a speck of Truth.

In the car they had their scientific instruments — thermometers, barometers, hygrometers, magnetic compasses, electroscopes, telescopes—and a collection of flasks and bottles of chemicals.

From the time of their disappearance till they were driven down to earth they had been within, and under, and above clouds, making experiments and observations, and gathering specimens of what they found in those unexplored regions.

This desire to penetrate into the secret places of the heavens has haunted the mind of man for centuries.

Early Efforts

In 1749, Dr. Alec Wilson conceived the idea of measuring the temperature of the upper air by means of kites bearing thermometers, and at Glasgow he carried out a great many experiments, carefully tabulating his results.

Others followed with similar experiments that gave the first scraps of knowledge regarding winds and air currents—information of much assistance to those who, not content with kite experiments, were determined to adventure themselves into cloudland.

Then Dr. Black of Edinburgh caused quite a sensation in 1767, by stating the belief that a bladder filled with "inflammable gas", as hydrogen was called, would rise to the clouds, and when in 1782 Cavallo's hydrogen-filled soap-bubbles actually floated away, as Dr. Black had predicted, the name of Cavallo passed on the lips of men throughout Europe!

How slowly—how very slowly does knowledge come! We smile now, we who know so much, that there could have been excitement over such a simple event. Yes, we in our wisdom smile, as those who follow us, but a

few years hence, will smile pityingly upon our proud inventions.

For some years two brothers, Joseph and Stephen Montgolfier, had been dreaming of probing the mysteries of aerial space and in November, shortly after Cavallo's successful experiment, they brought forth a balloon of their own fashioning, which, to their infinite delight and the wonderment of all beholders, soared into the blue upon the lifting capacity of hot air.

How did they fill their balloon with hot air?

They had noticed, as many another had done, that the smoke from chimneys curled upward. They pondered this simple fact, and setting to work built their balloon of a specially glazed paper, hung from it by means of chains a brazier, filled the brazier with wood, lit it, and away went the craft.

A model of this most ingenious aerostat with its gay paintings of the signs of the Zodiac is to be seen in the Aeronautical Section of the Science Museum, South Kensington.

But they were not satisfied, and continuing their labours, in the August of the following year, 1783, the Montgolfiers gave the world an even greater thrill. They sent up a huge *gas*-filled balloon from the Champ-de-Mars,

near Paris, right through the clouds to a height of over 3000 feet.

When they had announced their intention of doing this, so much interest and excitement was caused that the locality of the gas-filling plant was kept a dead secret, and when the envelope had at last been filled, the balloon was transported to the ground by night and under a strong military escort preceded by torch-bearers.

Imagine this weird procession: the rumble of wheels, the tread of feet, the ruddy glow of the torches and beyond all the enormous ball moving smoothly forward, and seeming in that fitful light like some monster from a strange land borne onward in a triumphant march.

"The cab-drivers on the road," says an ancient chronicle, "were so astonished at meeting such a dreadful being that they were impelled to kneel humbly, hat in hand, whilst the procession was passing."

When all preparations were completed a salvo of cannon signalled the ascent!

But the occasion was eminently worthy of its heralding, for, only a few months later, rare spirits, the Drakes and Frobishers of the uncharted, mysterious aerial seas, were themselves adventuring forth among the clouds.

Courage of the Pioneers

Not content for long with merely watching the ascent of balloons, they bent their energies to the making of a craft that would carry them up and enable them to find what was really there above the clouds, whether, as men said, the air suddenly ended, and there was nothing but a vast emptiness.

These early adventurers knew almost nothing of the upper air into which their questing minds were sending them. For aught they knew they would suddenly come to a void in which they would be suffocated; for aught they knew they might suddenly be seized by some mighty wind and carried up and up without end; they might be struck by lightning, or electrocuted by the electric charges within the clouds; the sun might scorch and burn them, rain and hail and snow beat them down.

Man was meant to stay upon the earth, it was said, and a terrible vengeance would befall those who went prying into the mysteries of the skies. (But happen what might, the leaping spirit of the few bold men would not be denied. It might be death, but they would go. The fear of death and the desire for knowledge. Which? Knowledge won, and like those other adventurers who went out magnificently across

the unknown waters of the earth to find new realms for their fellow-men, these others now ventured forth in the frailest of frail craft to bring to the world some knowledge of the aerial sea that envelopes our little earth.

CHAPTER II

The First Adventurers

When the Sun set Twice in One Day

The first adventurers in any new element are indeed courageous.

In the case of these explorers of the vast domain of the air, not only did they not know what they would find when they had arrived, but they had no knowledge of how the frail craft that was to take them there would behave.

All they did know was that the balloon was like a live thing, dancing and tugging to break free from the leashes that held it to earth. They knew that they could make it ascend by throwing out ballast, and descend by opening the valve and letting the gas escape. Beyond that, once they had embarked, they had given themselves into the keeping of a vessel over which they had not the slightest control.

Of these early adventurers M. Charles commands much attention, not alone for his courage, but for his intense desire for knowledge which sent him soaring up times out of number.

A Lone Ascent

On a December day of 1783, he had made an ascent with a friend. The light was fading and warned them to descend. When his friend and fellow-aeronaut, M. Robert, had been safely landed, Charles suddenly decided to go up again, and alone. There was no ballast at hand and no time to obtain any, and the sun had sunk below the horizon. No matter, he would set off, and jumping into the car of the balloon, he shouted to the peasants to release her. The balloon shot up into the air at a swift pace, so swift indeed that in a few minutes, looking over the side of the basket, Charles saw that the earth beneath him was nothing but a flat expanse as if a map had been spread out.

A few minutes more and the earth was a grey flat mass in which no object whatsoever could be distinguished. Then his fingers became numbed and he dropped the pencil with which he had been making notes.

Glancing up he found that the envelope which at the start had been quite flabby had swelled considerably.

How cold it was! It seemed as if he had suddenly passed from an almost spring-like warmth into an ice-chamber.

folding door

He opened the valve from time to time, but still he ascended. The cold was becoming yet more intense; the light was increasing.

He had already seen one sunset that day and now, whilst rapidly darkness was descending upon those on earth, he was passing just as rapidly into light. He was catching up the sun. In another minute, surely enough, the red rim of the sun rose again above the horizon as if the moment of sunrise had arrived.

Then the balloon ceased to move up or down, for it had reached the point where the weight of the air it displaced equalled its own.

At once the sun dropped beneath the edge of the world, and night had come upon the explorer floating in a profound silence beneath the stars.

Thus in the same day M. Charles had the unique experience of seeing the sun set twice.

"I rose up in the car," he tells us, "to contemplate the scenery around me. I beheld for a few seconds the circumambient air, and vapours rising from the valleys and rivers. The clouds seemed to rise from the earth, and collect one upon the other, still preserving their usual form, only their colour was grey and monotonous from the want of light in the atmosphere.

"The moon soon enlightened them, and

showed me that I had changed my direction twice. Presently I conceived, perhaps a little hastily, the idea of being able to steer my course. In the midst of my delight I felt a violent pain in my right ear and jaw, which I ascribed to the dilation of the air in the cellular construction of those organs as much as to the cold of the external air. I was in a waistcoat and bareheaded; I immediately put on a woollen cap, yet the pain did not go off till I gradually descended."

9000 feet Charles had reached and the temperature had fallen from 47° F. at the start, to —21° F., that is, he had risen into 11° of frost.

Ignorance Bars the Way

Had he not set off immediately that evening his expedition would have been prevented by order of no less a personage than the king himself.

Whilst Charles and Robert were coming down to earth the first time, there was hastening across the countryside a troop of horsemen, French noblemen, among whom was the Duc de Chartres. He had been following the flight of the balloon at the command of the king, who had ordered the arrest of the adventurers.

All through the ages those who have attempted to reach out into the unknown and break down

the barriers of ignorance have brought upon themselves the wrath and hatred of the narrow-minded.

A few powerful churchmen who had the ear of the king had persuaded him that those who tried to probe the mysteries of the heavens were deliberately affronting Providence. Man was meant to stay upon the earth, they said, not soar above the clouds, and so when Charles and Robert reached Paris they were surely arrested, and kept under restraint so that they should not again wickedly risk their lives in searching for that which man was never intended to know.

Fortunately, better counsel was brought to bear, the king shortly released them, and it was not long before they were again speeding upward to the clouds.

The Duc de Chartres, who had followed their route for miles across country to arrest them, had evidently been so fascinated by what he had seen that only the next year he joined M. Robert in an ascent from Paris, and was certainly given all the adventure he desired, for death came very close to them that day.

A Tight Corner

They had rapidly ascended to about 5000 feet, when without the slightest warning, they

started revolving. The balloon had entered an eddy, a whirlwind of great force, and they were soon spinning giddily. Just as suddenly, a heavy wind struck the craft and rocked it furiously.

Within the great hydrogen-filled envelope M. Robert, in order to test the effect of altitude upon air, had enclosed a small balloon containing ordinary air. It proved to be a very dangerous experiment.

The wind storm was threatening to wreck the car, and Robert reached up to open the valve to bring them down to calmer air. He pulled on the valve-cord but there was no escape of gas. He pulled and pulled again. The valve was certainly opened but no gas came forth. They were being swept up within the swirling column of wind and buffeted on all sides. What had happened was that the small air balloon within the envelope was pressed against the valve aperture and was preventing the outflow of the hydrogen. Here was an awkward predicament! They would ascend, and go on ascending until the balloon had reached its ceiling, that is, its greatest altitude. At this height it was quite probable that the low atmospheric pressure would cause the hydrogen to distend the envelope till it burst.

And in the meantime the savage winds were tugging at the envelope and wrenching at the car as if they would tear the flimsy structure to pieces and hurl the occupants to earth.

Something must be done, and done at once. There was only one way out, and the Duc de Chartres took it. He seized a banner, climbed up the rigging and pierced the envelope!

He jabbed at it twice and a rent of six or seven feet shot across the silk. The gas poured out and down they sped, the upward rush of the air now hissing in their ears and lifting their hair. They looked over the side and their breath was choked back in their throats. There were trees beneath them. Would they crash into one and be broken, or miss them and be smashed upon the earth? But fortune was with them, for they not only escaped the trees, but after coming heavily to earth, picked themselves up not much the worse for their shaking.

The Band of Explorers Increases

That year, 1784, saw a large number of attempts by various aeronauts to discover what forces were at play in the vast reaches of the air—electric forces, magnetic forces, the forces of strange and powerful currents. They

set out to find what happened to the air at various heights, whether it was composed of the same proportions of oxygen and nitrogen as at the surface of the earth; whether the sun's rays were more or less powerful the higher the ascent; and what effect great altitudes produced upon the human senses.

Queer Adventures

The experiences of each explorer differed greatly. Many ascents added nothing at all to knowledge; many gave results that contradicted those of previous flights, and not a few landed the seekers after truth into strange predicaments.

There were, for instance, those two intrepid aeronauts, Dr. Jeffries and Mons. Blanchard, whose names were familiar throughout Europe. They set off to cross the Channel from Dover to Calais, and for some reason, probably the down current associated with cold water, as soon as the balloon was over the sea it fell rapidly. Ballast was hastily cast out and still they fell. More ballast followed, and yet more, and just as they were giving up hope of saving themselves, the balloon steadied itself and floated in the breeze, with the car only a few feet above the waves.

All their ballast had gone, and they then

threw out everything that was detachable, including even the grapnel and its length of rope. But still they swept on perilously near the water. It was useless to hesitate. Out went their caps and the vessel rose some feet. A few minutes later Dr. Jeffries's coat went overboard, and they sailed on again. M. Blanchard's followed a little later. When the car dipped again, a waistcoat disappeared, and a mile or so farther on, another. The question then became: What distance is a pair of trousers worth? That solved, there remained a few undergarments and four boots.

Having *shed* their way thus across the Channel, they were approaching Calais, when an upward current of air caught them, lifted them up in a great looping sweep over the town and finally dropped them into the privacy of the forest of Guienne. We now know that there are up-currents caused wherever a wind is driving over rising land, and it was evidently due to such conditions that the travellers owed their safe arrival in France.

Signor Lunardi was caught in a somewhat similar plight, though he was at a much greater height. He was without ballast and found himself approaching a menacing thundercloud. He took off his cap, threw it overboard, and immediately rose out of the danger. But then

he passed into a heavy dark cloud where snow was falling thickly.

Away went his banner, and he shot up into clear air. When a great wind clutched at him he parted with his coat, and to escape from another thundercloud that was gathering he cast out his waistcoat.

It all sounds very much like a happy fairy story in which the hero has always magic in his hand to defeat the evil intentions of his enemy.

Lunardi's last magic garment to be used was his waistcoat, and that gone, he rose once more and was carried upon a wind back almost to his starting-point, where he landed safely in a cornfield.

Lunardi and Jeffries and Blanchard had happily come safely through dangerous adventures, and were preserved to make many more expeditions in the pursuit of scientific knowledge of the reaches of the upper air, but not so were M. Romain and Pilâtre de Rozier.

Their story, as will be seen, is indeed a tragic one.

CHAPTER III

The First Aeronaut is Killed

"A pioneer's catastrophe
  Drowned Icarus. 'T was long ago.
Wiser and not less bold are we:
  There is no fear for those that know."

James Flecker.

Adventure in new realms is always fraught with danger, and it is by the mistakes, often fatal, of the pioneers that those following after achieve success.

So it was with ballooning. After the Montgolfiers' surprising experiments with unmanned balloons it was not long before a balloon to which a car was attached made its appearance, and, with its passengers, ascended to the clouds.

There was great deliberation over the question of who should make the first ascent. Courage certainly was not lacking. Indeed, a number of high-spirited men pressed to be allowed to put this new craft to the test, but even the inventors themselves discouraged them, judging

that the time was not yet ripe, that a sufficiently reliable craft had not yet been devised. Among those who were only too ready to risk their lives in an attempt to reach the clouds was Pilâtre de Rozier, and it was not long before he obtained his heart's desire.

But at first it was so generally considered a wanton risk that must inevitably end in disaster, that after dogs had been safely sent up in the car of the balloon, and even cats and a sheep, it was suggested that a prisoner, preferably one convicted of murder, whose life was worthless, should be the first human being to leave the earth and soar into the air. It would be a way, as sure as the guillotine, they said, of ridding the world of a scoundrel. The pioneers of aeronautics had other views, however, and protested so vehemently against giving to an outcast of society the honour of being first to voyage in this new element that the idea was abandoned.

De Rozier had his way, and made several successful ascents, to the unbounded admiration of the great majority and the violent condemnation of not a few who viewed his intrusion into the heavens as nothing less than an affront to Providence, wicked and presumptuous, which would surely call down upon his head a terrible punishment.

How must those have raised their eyes in pious satisfaction when a little later. their prediction was fulfilled.

Man cannot stay still—he must progress, must move for ever from one achievement to another.

A Brave Man

De Rozier, from desiring to penetrate the clouds, passed on to a fresh ambition. He determined to travel in the air from France to England, and he determined to be the first to do so.

The multitude of his admirers increased as did the fervour of their admiration. He was the splendid hero in tens of thousands of hearts. His courageous project was awaited eagerly, impatiently.

Yes, impatiently, for he had given out that he would make the attempt, and day by day he hesitated. The balloon was ready, his plans were made and still he held back.

De Rozier was a very brave man but he was not a reckless man, and day by day he was convinced that the winds and the weather would inevitably defeat him and bring him to disaster.

The wind must give some promise of assistance, for it is only by the currents in the air that a balloon is carried; there is no way of

guiding or propelling it; the only control is an upward movement by dropping ballast, and a downward movement by a release of gas.

It was madness to attempt to reach England with a strong west wind blowing.

But the fickle public grew tired of waiting, grew so tired that they began to question his courage. All his fine intentions were idle boasts —he was afraid. Winds or no winds, he should have thought of all that before making his boast. Many of those whom he considered his friends lost their confidence, and their doubt of him, who knew himself to be as daring as any man, cut him to the heart.

Then the worst possible thing happened. The aeronaut, Blanchard, who had vowed that he would be the first across the Channel, set off whilst his rival was still waiting, and after a most successful flight brought his balloon down safely on French soil.

De Rozier was not only a brave man—he was magnanimous. He was among the first to welcome Blanchard and offer him sincere congratulations.

The Gateway to the Heart of his Friends

He returned to his own quarters at Boulogne. It was June—the June of 1784. The winds were contrary and in his heart he knew he had

little chance of reaching England. But he could not rest. The scorn that he knew was in the minds even of his friends, ate into his heart and chilled his spirit.

He would not wait longer. Though he knew he was courting disaster he would prefer death to life without the respect and love of his friends.

On the night of the 14th June he sat alone brooding. When, months ago now, the Montgolfiers had refused to allow him to risk an ascent in their balloon he had reasoned with them, using all the argument and persuasion at his command.

"We have lived long enough," he asserted, "when we have added something to humanity."

He had added that something—he had helped to show that man could voyage among the clouds: that indomitable man could lift the veil of Nature.

He was not afraid. He would even now regain the admiration and faith that had in so short a time been taken from him.

He went out and sent up small balloons, and they showed him plainly that the wind was as adverse as before.

He examined his own balloon with his fellow-adventurer, M. Romain. It was being inflated and was in excellent condition.

He had determined to make doubly sure of remaining long enough in the air by using not only hydrogen gas in the envelope but to increase its lifting power by heating the gas.

Therefore he had a heating apparatus so that the hot air from it should ascend into the envelope.

A fire anywhere near hydrogen gas! It was a fatal error.

He was advised to take some sleep. "Sleep, sleep," he cried, distraught in his impatience to get away, "there is no more yet for me: I must be off—I must cross the sea, though it swallow me up—it is the only gateway that remains to me, in order to return to my friends."

How greatly, how bitterly the loss of his friends' respect troubled him.

"My fortune, my glory, my life are all on that side (England)," he protested. And so he started, he and his loyal companion Romain.

The balloon rose rapidly under its double lifting force of hot air and hydrogen. The crowd that had assembled watched it pass up through a thin cloud which for a little hid it from sight. Then it emerged and travelled away, caught by the strong northerly wind.

He was away at last, but what were his chances? The question was asked a thousand times by the watchers there below, but who

could tell, and not one answer touched the horror of the tragedy.

As they gazed up at the departing balloon, now at about 1800 feet, a strange flash suddenly lit the envelope to a gleaming brightness as if a stronger light had fallen upon it.

To their startled eyes came a violent flame that leapt up fiercely to the top of the balloon and swept beyond.

It was all so sudden. In one, two, three seconds, so it seemed, the balloon was wrapped in flame.

A flaming mass, every moment becoming smaller, was rushing to earth.

The answer to the thousand times repeated question of a minute or so ago was given.

Eyes would have been turned away, but were held in dreadful fascination.

Then the crowd broke, and there was a breathless rush in the direction of the place where the burnt-out balloon had crashed.

Two nude bodies were picked up, their clothes completely burnt away. Romain was still breathing, but De Rozier's body was scorched and utterly broken.

He had indeed found the gateway back into the hearts of his friends.

CHAPTER IV

The Never-ending Quest

"Till a voice, as bad as Conscience, rang interminable changes
On one everlasting Whisper day and night repeated—so:
'Something hidden. Go and find it. Go and look behind the Ranges—
'Something lost behind the Ranges. Lost and waiting for you. Go!'"

—*Kipling*.

Danger and Disappointment

The dreadful fate of De Rozier and his companion, whilst it shocked Europe, had little or no deterrent effect upon their fellow-adventurers, those new Knights of the Air who had set themselves the splendid task of revealing to the world the mysteries of the strange element that envelops our little planet.

That task is not only a splendid one—it is as vast as space itself, and will remain unfinished to the end of time.

What mighty forces were at play within and about the clouds? What ruled the winds? Where was the birth of snow, of hail, of rain? At what

height would human life cease to be possible? What were light and heat and how were they conveyed from the sun to the earth? Did the air stretch away upward to the stars, or did it cease and, if so, where, and what was there then?

A myriad questions came up for answer. As soon as one discovery was made a fresh problem presented itself. A thousand years would bring the traveller in this unknown realm of space but a little way upon his journey.

How slow, how painfully slow, is the discovery of even one small grain of truth will be realised from the fascinating story of these adventurers.

It is not as though one expedition into the air, no nor twenty, will give a certain piece of knowledge. In many instances hundreds of journeys and experiments have been made before one small truth has been discovered.

Knowledge of the upper air, knowledge of any and every single thing—is a great shining temple for ever being built by the labours of a host of workers, each puny labourer bringing his own mite, obtained often after enormous hardship and often too in the very face of death.

There was that question of the composition of the air—one grain of truth. It was known

that at the earth's surface it consisted roughly of four parts of nitrogen to one part of oxygen with small quantities of carbon dioxide and water vapour.

Now, was the air at increasing heights composed of this same mixture, and in that same proportion?

In 1804 Professor Robertson went up from St. Petersburg with the well-known scientist, Sacharof. They were off in search of their tiny morsels for the shining temple of truth.

They hoped to bring back information concerning many things besides the composition of the air, among which may be mentioned the flight of birds, the effect of great height upon colour, what electric and magnetic forces were in and about the clouds.

Up they went, then, making observations and notes at many different heights. Very carefully they carried out experiments with their chemical and physical apparatus. At every 200 feet they filled with air, flasks that had been exhausted, and safely protected them, meaning to examine their contents in the laboratory upon landing.

They passed through clouds, and on their instruments were registered the electrical forces at work within those clouds. As they sailed up higher they filled other flasks with the air

in which they were floating, to test later for the amount of water vapour present.

They took readings of temperature and barometric pressure, and tested the effect of light upon various chemicals.

Fog spoiled their effort though. So thick was it beneath them that the earth was completely hidden.

They were unable to escape the fog and mists, and so decided to descend.

The valve was opened and down they dropped, down through the air that was as translucent as frosted glass. They were descending too rapidly. Soon they would be close to earth. They threw out, one by one, every object in the car. The rapid descent of the craft was checked, but still the speed was too great. There would be a bad landing.

They took off their coats and woollen garments and wrapped the scientific instruments, the chemical apparatus and their precious flasks of air carefully within them. Then they attached the bundle to the grapnel and gently lowered it. It touched the ground and at once this reduction of weight sent the balloon up with a bound. Down it came again, the precious bundle being pulled this time roughly over the ground. At last a safe landing was made, but when Professor Robertson ran to the bundle

and opened it, he found, to his great disappointment, that all within had been smashed. Thus his efforts had been in vain—he had very little indeed for all his labour to bring to the temple of knowledge.

A Daring Expedition

Hundreds of such adventures ended in failure or disaster.

In the previous year, on the night of 7th October, 1803, Count Zambeccari with Dr. Grassati and Pascal Andreoli set off from Bologna in a fire-balloon.

They took a lantern with them by which to read their instruments, and they were out on the same quest of the electric forces at work after the sun had been set some hours.

It seemed to the crowd of watchers that their balloon was no sooner released than it was almost out of sight except for the faint glow now and again of the brazier slung beneath which was supplying the hot air to the envelope.

Rapidly the balloon climbed to a great height, so rapidly that the cold and rarefied air coming suddenly upon them struck down two, the Count and the Doctor, who fell unconscious to the floor of the car. It was fortunate for them that Andreoli was not so easily overcome. He managed to bring the craft down into warmer,

15,461

denser air, which revived his companions. But now they found themselves drifting over the Adriatic Sea at a none too safe altitude, and in darkness, save for the glint of the stars. The lantern had burnt out, they were chilled now and weary, and they were falling fast towards the water.

There was no means whatever of summoning aid—no means as in these days of radio, of sending a signal of distress.

The car struck the sea and a cloud of water wetted them to the skin. They threw out ballast and rose from the waves. More ballast sent them up among the clouds, thick and cold and blinding. Their clothes hung wet and chill about their limbs. Yet again more ballast was dropped and they rose out of this deep layer of cloud, passed through a clear region and were once again swallowed up in a cloud colder and denser than that other. A dark wall of moisture was sliding swiftly downward; they were in a cylinder whose grey gloomy surface was pressing in upon them and gliding silently, sombrely by them. Would this falling wall never end? Its movement grew less, and ceased, and then they were shut in, in a cold, damp darkness. The balloon had become stationary. Throw out more ballast! Ballast!

The words had been shouted but no sound was heard, for deafness had come upon them all.

But the ballast was dropped and that dark menacing wall at once began to slide down past them again.

After what seemed an age the wall grew thinner, and they sped out through the top of the cloud. Clear at last! A sigh of relief was breathed. Within a few minutes they had entered yet a third layer of cloud, and again that sliding wall pressed upon their car and upon their straining nerves.

Everything was wet about them, and their clothes, like coverings of ice, were stealing the last flickerings of warmth from their bodies.

Down they went again through cloudland, the dark walls now sliding swiftly upward and setting up a new giddiness in their brains.

Their hearing returned to them. Down below there was the low murmuring of the sea, and they shuddered.

In the darkness they fell again upon the waves which threatened to wash over and swamp them.

Dawn came chill and grey and showed the adventurers sick, weary, and well-nigh hopeless, caught upon a breeze which was carrying them to the coast of Istria.

For nearly four more terrifying hours they drove on, being alternately lifted high and dashed down upon the waters.

Not until eight o'clock that morning were they rescued. Antonio Bazon sighted the balloon making its mad capers over the sea, and changing his course he put his vessel across its path. With the greatest difficulty the three unfortunate explorers were lifted aboard and taken ashore.

They were all in sad condition, Count Zambeccari especially suffering so greatly that for some days his many admirers feared for his life.

A man of lesser spirit, having recovered from such an experience, would have been content to leave the exploring of the air to others. Not so Zambeccari. He was soon adventuring among the clouds again, and made many ascents until at last in 1812 he went up from Bologna on his last flight. His balloon came down in some great trees, caught fire, and the courageous Zambeccari, jumping out in a last effort to save himself, crashed to earth and was picked up dead.

His many flights had thrown light on the question of the temperature of the upper air. He had taken hundreds of thermometer readings at different altitudes and compared the

various sets of readings in the hope of discovering some definite law.

He had brought back, too, information concerning the electric forces existing in the clouds at certain times and under certain conditions of wind and temperature.

Such were the tiny contributions of this heroic worker to the great temple of knowledge.

CHAPTER V

Other Explorers Follow On

Andreoli, the Courageous

Each new adventurer into the vast domain of the air endeavoured to verify and add to the discoveries of those who had gone before.

The effect of great altitudes, for instance, on the human senses was carefully noted and showed much variation.

Whilst one would be overcome at 15,000 feet, another was unaffected at even 20,000 feet.

There were Andreoli and Carlo Brioschi, the Astronomer Royal at Naples, who ascending from Padua, kept a close observation on the reaction of their bodies to the rarefied air.

At 15,000 feet Brioschi's heart began to flutter in an alarming manner. It was palpitating violently, 1000 feet higher, and his breathing was troubling him greatly. He was not gasping, but felt the need to breathe at almost twice his normal rate. There was a

peculiar sense of lightness about his body, and yet when he tried to lift his right arm he found it would not answer to his will. He suffered no pain but there his arm hung close to his side with all the lifting power gone from the muscles. He tried the left arm. That also hung powerless from the shoulder.

Andreoli glanced from the drowsed face of Brioschi to the barometer; it read 15 inches. They were therefore 15,000 feet up. A little later Brioschi lay quite still in a torpor, as deep as if he were chloroformed, and at that moment Andreoli noted that the barometer was down to 12 inches, which meant an altitude of 23,000 feet.

Instead of opening the valve to descend, with his fellow-adventurer lying there unconscious, he calmly took the immense risk of going on up into the intensely cold thin air.

Up and up he sped. At an altitude of 28,500 feet, when the barometer stood at 9 inches, all strength went out of his left arm. It was the beginning of that same unconsciousness that was wrapping his friend now in an ever-deepening sleep.

Delay but a little longer and it would be too late. The will could command but the body would not obey. Ninety-nine men out of a hundred would have reached up with the right

arm and pulled the valve cord to descend. Andreoli was the hundredth man. At the immense height of 29,000 feet and with his companion lying as if dead, he still allowed the craft to bear him on into those strange regions, cold, silent, intensely silent.

How much longer he would have gone, who can tell, for just after he had read the barometer at 8 inches (32,000 feet), a loud report shattered the profound silence.

It hit upon his ears and stunned him. He had been utterly unprepared in that calm loneliness of space for such a thing.

Only too well did he know what had happened. The balloon had burst!

At probably 32,000 feet above the earth, in a silence like that of death, and with the only other human being in that lifeless world lying motionless at his feet, the balloon had burst.

Down it sped and Andreoli was helpless. What could he do with the fabric of the envelope torn and flapping in the swift upward wind as the craft rushed to earth!

When they had come down to warmer and denser air Brioschi awoke. Could there ever have been so tragic an awakening?

As they dropped almost like a stone they watched with returning hope the broad fragments of fabric tugging against the cordage

and filling out in the swift upward rush of the air caused by their rapid falling.

Surely they were slowing up? The burst envelope was acting as a parachute and checking their speed. The upward wind was becoming less.

As they neared the earth they knew they had a chance. They braced themselves for a heavy crash. It came. For a time they did not know exactly what had happened and then they found themselves shaken but safe, back once more on the familiar earth and not a great distance from a tomb—the tomb of Petrarch.

On the Track of Truth

What had those two added to the knowledge of the upper air? They had done much. They had penetrated farther into that strange domain than any other explorer; they had come to grief through a mistake that others, on their guard now, would benefit from; they had found that life was possible at great heights and that those heights varied with the individual; and they had carefully noted what effects increasing altitude had upon hearing, sight, the rate of respiration and the action of the heart.

Besides all this they had discovered a strange behaviour of the winds. It seemed that they passed out of a thick slab of air travelling in

a certain direction, into another slab above it, which moved in almost an opposite direction.

This question of winds, as will be seen, occupied the thoughts of many another aeronaut. In fact the explorers all down the ages followed up the interesting investigations in every direction of those who had gone before, verifying or correcting and extending. Thus those problems of winds, temperature variation, effects of height upon the human senses, and such matters, engaged the attention of most aeronauts. It was by their united efforts that slowly, very slowly, strange truths were discovered and stated.

What remarkable adventures these seekers after knowledge encountered!

When Sadler went up from Dublin he could have little anticipated the decision he was called upon to make to save himself.

His balloon was sailing away when a swift adverse wind caught him, and rather than be carried away beyond the possibility of help he released the gas and came down in the sea.

A vessel was close at hand and came at once to his assistance. The wind was tugging at the still partially inflated envelope and causing his car to drag along the surface of the sea. Any moment it might dip beneath and the helpless Sadler be swamped and drowned. A swift

decision was made. He shouted to the vessel to ram his balloon. The captain understood, and with fine judgment sent the boat straight at the globe dancing there above the waves.

His bowsprit, at the very first attempt, pierced the envelope and stopped its capers once and for all.

By this method, perhaps the only instance of its use in the whole history of aeronautics, not only had Sadler's life been saved but his balloon was secured, comparatively little the worse.

Helpless Above the Clouds

Even more startling was the experience of the younger Mr. Sadler. Setting off from the Green Park, London, he reached a great height with the temperature falling so low that when he attempted to open the valve and descend he found that it had become frozen and would not budge. Higher and higher he sped and before he could pierce the envelope, the net burst at the very worst place possible—right at the top. Then the envelope began to squeeze through the rent, which meant that soon or late it would escape and fly on upwards whilst he in his basket would crash down to earth. His peril was sufficient to strike panic into any but the coolest brain. There was but one way of escape and happily he seized upon it. Rapidly

he wound the long neck of the silken envelope around his body under the arms and fixed it with a fourfold knot from which he did not allow his hand to move.

But the valve was still frozen fast so that he was carried on up into colder and colder air.

Wellnigh frozen to death, and gasping for breath he reached the extreme height of which the balloon was capable—its "ceiling"—and for a time drifted in the air current that was moving there.

The gas within the envelope gradually contracted in the extreme cold and probably too escaped from some leak, so that after what seemed an endless time of torturing strain, he came to earth in a field not far from Gravesend.

The sensations he experienced confirmed the testimony of those others who had penetrated the upper reaches of the air.

He, too, found that profound silence which had so impressed the earlier travellers. His heart had quickened its beating until at the greatest height it had palpitated violently; his breathing was short and rapid, acute pain had been in his ears, and his tongue and throat were parched.

The same torpor had crept upon him in which he had felt he could have passed painlessly to death.

How very slow was the advance in knowledge of the vast aerial domain!

Gay-Lussac and Biot set off from Paris bent on discovering what electric and magnetic forces existed at varying heights. From 7000 feet up to 13,000 feet they made experiment after experiment. All their labours ended in a great disappointment for their results were exactly the same as if the same experiments had been carried out on the earth.

But they were not satisfied. Again Gay-Lussac prepared for an ascent and this time set off alone. He took with him instruments to register the electric and magnetic condition of the clouds and of the air immediately above and below them; and flasks from which the air had been exhausted, in which he intended to bring back samples of the atmosphere at different heights.

This time he reached 23,000 feet—a splendid effort, and obtained much greater success with his instruments.

His magnetic needles vibrated more slowly than on earth, which confirmed his theory regarding the diminution of the earth's magnetic field with increasing altitude. In the vicinity of some immense cumulus clouds he found strong charges of electricity. There was an intense blueness about him and the air was very dry.

Is This Truth?

His many thermometer readings gave an interesting result. There was an almost regular fall which led him to believe and state that the temperature declined 1° F. with every 300 feet of increase of altitude.

That was certainly the truth to which his set of readings pointed and for a considerable time the conclusion was held to be correct.

On reaching earth and testing the air brought down in the flasks he found that in composition it was exactly the same as the air at the earth's surface. The proportions of oxygen and nitrogen, that is, were the same. The only thing which differed was the density.

With regard to that fall of temperature of 1° F. for every 300 feet increase in altitude, forty-six years after Gay-Lussac had stated his belief, two aeronauts determined to reach a height of 40,000 feet in order to test that finding.

They did not reach that height, however, for after they had shot up and passed in two minutes out of sight in a great cloud, the envelope swelled and pressed down upon them as they sat in the car. Then it burst and they came down almost as swiftly as they had gone up, but by throwing everything out they managed to break the fall and landed, bruised only, in a vineyard.

But up to their highest point, about 20,000 feet, they had found that almost regular fall in temperature of 1° F. in 300 feet.

Undaunted, only the next month, they went up again and this time reached 23,000 feet. As before, up to 20,000 feet there was that steady fall in temperature but beyond that they came upon a phenomenon of immense importance.

After 20,000 feet the thermometer which read 15° F. fell in the next 3000 feet to −39° F. Here was a startling fact. A fall of temperature of 54° F. in only 2000 feet. There was the greatest need here for further investigation.

Moreover, at 8000 feet they had entered a cloud from which they did not emerge until at 23,000 feet. A cloud 15,000 feet thick, and in its upper region of an intense coldness. Why should this be?

Two years later Mr. Welsh sailed away in the great Nassau balloon which had made many safe and remarkable journeys.

He went up to about 23,000 feet, taking many thermometer readings, and once again that regular 1° F. fall was observed.

It seemed that at least one law governing the mysterious realm of the air had been discovered.

We shall see.

CHAPTER VI

A Big Step into the Unknown

So far the great aerial territory was still almost unknown. What governed the formation of clouds, their varied forms and density; under what laws the winds were ruled; by what means light was transmitted to the earth; to what height the air extended, and, if it ceased eventually, what lay beyond——?

All these and a hundred other problems were unsolved and fascinated the minds of many scientists and philosophers.

Whilst this was so, man was bounded by his little world, miraculous in itself beyond all doubt, but nevertheless only a grain of sand upon the infinite shore of the universe.

In 1862 the British Association, then, as now, a body of the most eminent scientists of the day, commissioned Coxwell, a professional balloonist, to make a series of ascents.

An observer was needed, a man of science upon whose powers of observation and accuracy

of experiment the utmost reliance could be placed.

James Glaisher, a member of the British Association, offered his services, which were gladly accepted.

Immense interest throughout Europe was aroused by the project.

Glaisher's efforts were concentrated upon the following tasks:

To compare the readings of a mercury barometer and an aneroid, in order to find the relative value of the instruments for registering altitudes.

To find the " dew-point " at various altitudes.

To find the temperature, pressure and electrical condition at different heights.

To find the composition of the air, and the proportion of oxygen as the temperature fell.

To make sound observations.

To examine the rate and direction of air currents, under and above, and in clouds.

To examine the temperature, the density, and the thickness of certain types of clouds.

To test samples of air brought down from various heights.

This was a most important adventure which,

it was hoped, would gather up all the uneven threads of knowledge into one orderly pattern of definite form.

The eyes of the scientific world were therefore turned upon Glaisher and Coxwell in the year 1862.

So far, it will be remembered, about 30,000 feet had been the greatest height attained.

Glaisher determined that as far as humanly possible there should be no failure. For three months, therefore, before the first ascent he mapped out the plan of action in its minutest detail, gathered together all the necessary apparatus and scientific instruments, practised himself thoroughly in their use, and what is more, practised using them in a space no greater than that provided by the car of the balloon. He spent hours arranging the apparatus on the board which he intended to use as a bench in the car.

To ensure the safety of the instruments he proposed to tie each in its place with string.

Preparations were completed and Coxwell had taken *Mars*, his great balloon, to Wolverhampton.

A great disappointment came. During the inflation with coal-gas a hurricane struck the envelope, which was not of silk but of a particularly strong American cloth, and made a

slit which ran upward and almost entirely round the seam at its greatest girth.

A week was spent in its repair and then followed another week of heavy weather. Glaisher could remain but one day more at Wolverhampton; if the ascent were not made then, on the morrow, it must be postponed indefinitely.

The next day, 17th July, came, and with it a terrific gale. So buffeted was the balloon that it was impossible before the ascent to arrange and fix the instruments as Glaisher had so carefully planned.

It seemed madness to set off in such dreadful conditions, but both Glaisher and Coxwell were anxious to start, and so at 9.43 a.m. the *Mars* was released.

In six minutes they had reached 4467 feet and entered the first great cumulus cloud. For over 1000 feet they ascended through a thick grey mist that muffled all sound and rendered them sightless.

Light broke through upon them at 5800 feet, but a cumulo-stratus cloud lay directly in their path above them and at 8000 feet they were moving swiftly through it.

How they Measured Altitude

How, it may be asked, were they able to measure with such accuracy their altitude?

It is intriguing to follow the steps that man has taken to solve this problem.

The method employed requires the combined skill of the physicist, the mathematician, and the scientific instrument maker.

Picture a tall pile of rubber blocks, all of the same size, standing on top of one another. How would the appearance of the blocks at the bottom of the pile differ from those at the top? The lower down the pile the greater the weight above, and the more the lower blocks would be squeezed together and flattened out. After observing a few such piles it would be possible to know the position of a block in the pile merely by noting its size, the very thin ones being at the bottom and the thick ones at the top.

A sample cubic inch from the bottom and one from the top would have very different weights, since there must be far more rubber squeezed into a cubic inch at the lower end of the pile.

Now we, on the earth, live at the bottom of an ocean of air that is piled up above us, as we already know, to a considerable height, probably about two hundred miles. A two hundred mile pile! How the lower layers must be pressed together by the weight of all that lies above! The air, of course, gives no visual indication

of its density. It can be weighed, however, and, as we have already observed, weight is a very good indication of position in the pile.

The weight of the air is found by a barometer. By calibrating the scale of the instrument in thousands of feet, instead of inches of mercury, it becomes an altimeter.

To return to the narrative, at 10,000 feet a most magnificent scene of sun-lit clouds spread around them, so that it seemed they were floating in a colourful land of many mountains and valleys—a beauteous land known only to themselves and whose hues and shapes changed from beauty to fresh beauty, minute by minute.

The only sound to break the hush and the sense of their complete isolation was the music of a band coming up to them softly from the hidden earth.

At 12,000 feet, looking down, they saw the ground of their new world open for a space and reveal the old world distant and vague, and then close again.

They Come Upon Fresh Tracks

Glaisher had been very busy, and by this time he had all the apparatus and instruments arranged on the table, and tied firmly with string, the table being also lashed for safety to the car side.

Coxwell was occupied with the management of the balloon, giving his attention to the valve, the ballast, the barometer in the regulation of the speed of their ascent.

Both had put on extra clothing at 10,000 feet, for there was the steady fall in temperature of 1° F. for every 300 feet to prepare for.

Already the thermometer showed a drop of from 59° F. to 26° F. And now, carefully watching these thermometers, Glaisher saw to his surprise that they showed no change right up to 13,000 feet.

That surprise increased when between 13,000 feet and 15,000 feet the temperature rose to 31° F. and continued to rise, so that they threw off all their extra clothing. At 20,000 feet, at which height Gay-Lussac had found the temperature to be 15° F., the thermometer now gave 42° F. Moreover, when they dropped from this height, the temperature fell rapidly to 16° F.

Here were facts that decidedly contradicted that 1° F. fall in 300 feet law and showed the necessity to examine each detail under every possible condition of time and place and season.

How they Measure Dew-point

Of the greatest interest were the numerous readings taken of dew-point in order to determine the humidity of the atmosphere.

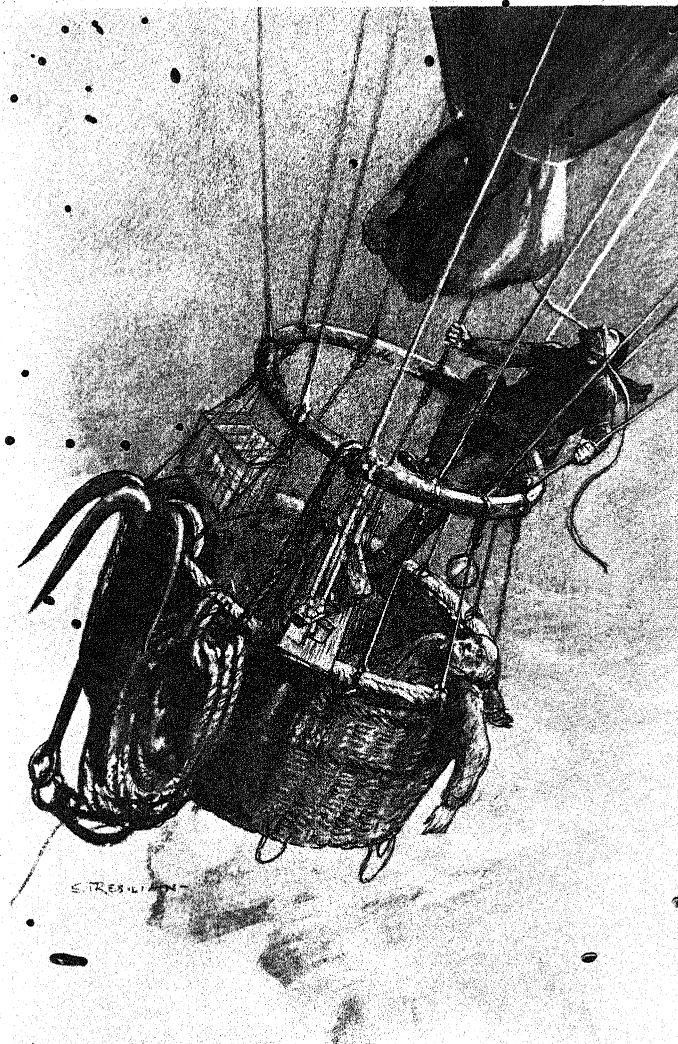
What is this humidity of the air which meteorologists are continually determining?

The humidity is simply the amount of water vapour present in a given quantity of air. This alone, however, is not of much value. Merely to say there were 35,000 spectators at a football match gives no idea whether they saw the game in comfort or were painfully overcrowded. What is necessary to know is whether the ground was a quarter, a half, or quite full.

It is the dampness of the air, or its *relative humidity*, that is required. This is expressed as a ratio of the actual quantity of water vapour present in the air, to the maximum amount it could hold, at the same temperature.

Our sensation as to dryness, or dampness, of the air depends on this ratio, and not on the absolute quantity present in the atmosphere. Thus on a cold winter's day, when the air is saturated say at 41° F. the air feels very damp, while if the temperature had been 59° F. the same quantity of water vapour would not nearly saturate it (the humidity would now be 50 per cent instead of 100 per cent) and it would feel comparatively dry.

There are several methods by which the relative humidity of the air may be measured. A widely used instrument consists of two exactly similar thermometers placed close to-



COXWELL AND GLAISHER NARROWLY ESCAPE DEATH

Page 76

gether. The bulb of one is enclosed in a muslin bag kept moist by a wick dipping into a small vessel containing water. The dry bulb registers the temperature of the air. If the air is not saturated, that is, if it is able to hold more water vapour, then the moisture in the muslin will evaporate. The energy required for this process is taken partly from the glass of the wet bulb and the mercury which it contains. These in consequence suffer a loss of heat and a resulting fall in temperature. Should the air be saturated there will be no evaporation and the two thermometers will record the same temperature. Very dry air will cause considerable evaporation, and therefore a large difference between the readings of the thermometers. The amount of the difference is thus a measure of the relative humidity of the air. Tables have been prepared from which the relative humidity may be read at a glance when the two temperatures are known. Such an instrument, when suitably arranged, can be used in manned balloon ascents.

In his experiments Glaisher made use of the dew-point in calculating the relative humidity.

If air containing water vapour is cooled, a temperature will at last be reached at which the vapour saturates the air, and any further cooling will cause condensation of some of the

vapour into water. This temperature is that at which the air would be saturated if it contained the same quantity of water vapour that it had at the original temperature, and is called the *dew-point*.

Tables have been prepared from which it is possible to obtain the relative humidity if the temperature of the air and the dew-point are both known.

The problem thus resolves itself into the determination of the dew-point.

Clearly a *dew-point hygrometer* is an instrument capable of cooling the air until condensation takes place, or dew is formed.

The temperature of the air is commonly reduced by the evaporation of some volatile liquid such as methylated ether. By means of an aspirator, air is drawn through a small quantity of ether contained in a test tube surrounded by a silver thimble upon the polished surface of which the deposition of dew may be easily observed. The temperature at which this occurs is noted. The aspirator is then stopped and the thimble begins to warm up until it reaches the temperature of the surrounding air. During this process it is closely watched and at the instant the dew disappears the temperature is read again. The average of these two readings is the dew-point.

Glaisher, then, tested the humidity of the air by taking many readings of the dew-point. Just before they started when the temperature was 59° F. he found the dew-point to be 55° F. At 4000 feet with the temperature at 45° F. it was 33° F. and at 10,000 feet in a temperature of 26° F. the dew-point was 19° F.

Thus up to 10,000 feet the air became damper. When at 15,000 feet the temperature so unexpectedly rose to 31° F. the humidity had changed, but slightly for the dew-point came out at 25° F. But at 20,000 feet the dryness had increased greatly, for with the thermometer at 42° F. the dew-point had now fallen to 24° F.

Many thousands of readings of the dew-point at varying altitudes have been taken by aeronauts, and their records have been supplemented by innumerable experiments with the ballon-sonde, the important use of which will be described later.

Comparison of all these results showed that dew-point was not just a freakish condition but obeyed a fairly definite law. Humidity is found generally to increase with increasing altitude up to about 6000 feet. Above this height it tends to become less.

Glaisher expected to find that the higher he ascended the weaker would become the earth's magnetic field.

Note the care and minuteness of his records: At 18,844 feet eighteen vibrations of a horizontal magnetic needle occupied 26·8 seconds; at 20,238 feet twenty-eight vibrations took 43 seconds; at 22,537 feet the magnet failed to vibrate at all.

At 18,844 feet his pulse was 100; at 19,415 feet, palpitation of the heart began, the chronometer sounded much louder, and his breathing became faster; at 19,435 feet his pulse had reached 108 and his sight was affected so that he could not read the smaller scales of his instruments; and the beating of his heart became audible. His lips and hands became blue—a dark blue. At 21,792 feet a feeling of sickness passed over him and he could scarcely see to continue his experiments.

22,357 feet was their greatest altitude and as they descended Glaisher continued his observations until at length a safe descent was made at Oakham in Rutlandshire.

So much for the first successful adventure. It had yielded results of the greatest importance and given Glaisher and Coxwell a fine determination to explore heights never before reached by man.

It was with the spirit of a splendid purpose leaping in their hearts that they set out again on the greatest of all their adventures.

CHAPTER VII

The Record Ascent of Coxwell and Glaisher

They Depart in the "Mars"

We have already spoken of the immense care and accuracy with which Glaisher, and indeed the other explorers, carried out their observations and experiments. Professor Glaisher left nothing to chance when it was possible to make preparations. You will remember that he had even practised working his apparatus in a space just the size of the balloon car, in order that he should not be handicapped when he was hurriedly working miles up above the earth.

Now at three minutes past one o'clock p.m. on 5th September, 1862, he and Coxwell are looking out over the side of the car of their balloon the *Mars*, that is being held down in a field on the outskirts of Wolverhampton.

"Are you ready?"

"All ready."

"Release her!" shouted Coxwell.

The *Mars* rises swiftly into the misty air, towards a great cloud floating steadily across the sky.

Whilst Coxwell is occupied checking the rate of ascent, testing the valve from time to time, and keeping a close observation on their direction, Glaisher with note-book in hand is closely watching instrument after instrument.

He turns to the hygrometers and finds that the dew-point is 37·9° F., his eyes move quickly to the thermometer which registers 41° F., and then are transferred to the barometer. His observations must be rapid, for three separate readings are to be made and noted and if the third, with the barometer, be bungled, the other two are worthless for they are rising swiftly. Coxwell will assist by reading the barometer and giving the altitude, but just at this moment he is too busy. Glaisher has also to note the time, the effect of the height upon his hearing, the sound of his voice, the appearance of Coxwell's face, the appearance of his own in a mirror, the effect of the sun's rays, the colour of the sky, the nature of the clouds above and around them, the appearance of the earth beneath.

"A thick cloud above us," calls Coxwell; "we're going straight for it."

There is complete silence again. Glaisher

looks up from his instrument table. The silence is broken once more. It is the sound of a gun coming clearly and yet as from a far distance.

Yes, it was the report of a gun come to them from the earth beneath.

A mist suddenly wraps them round. They are in the cloud and an impenetrable greyness shuts out everything. No sense of movement, no sound, no sight and a damp coldness.

Glaisher takes the barometer reading at the moment of entering the cloud. He notes the dew-point. It is 36·5° F. He reads the thermometer. That too is 36·5° F. The air is saturated then. In two minutes the greyness lightens, the sun appears dimly, long grey wreaths fly past them. The barometer shows that the cloud was 1100 feet thick.

Through Delight to Danger

What a glorious view! A flood of sunlight lightens their spirits. They are floating in a pure blueness and gaze down upon a vast country of clouds with range upon range of gleaming mountains, deep valleys all blue and shadowy, and snow-capped irridescent peaks. Glaisher seizes his camera. But the craft is moving up and revolving too rapidly to allow of successful photography.

"We're two miles up."

"Yes, two miles," Coxwell confirms.

"Time, 1 hour 22 minutes, temperature freezing-point, dew-point 26·0° F." Glaisher informs his companion.

In 19 minutes they have reached two miles. The temperature has fallen from 59° F. to freezing-point—27 degrees. The dew-point has changed from 50° F. at the start to 37·9° F. at 5000 feet and then in the cloud to 36·5° F. (saturation) and again at two miles to 26° F.

The air then has changed from moist to moister, to less moist.

In six more minutes they rise another mile. The temperature is 19° F. and the dew-point 13° F. The air then is getting drier and drier.

And now, to Glaisher's disappointment, the hygrometer fails to work.

It is getting very, very cold, the blue of the sky is deeper than it was, the silence except for the occasional slap of the cordage is profound. They are beings alone in a vast, silent, ice-cold, but gloriously lovely realm. Glaisher points downward to where the earth appears for an instant, dim and vague, through a swiftly closing gap in the clouds.

Coxwell does not answer and Glaisher looks hard at him. He is panting. Every time he moves to throw out ballast or to read the barometer, or to attend to the rigging, Coxwell

pants just as if breathless from a severe race.

But Coxwell is the hero of a hundred ascents. There is no need to be anxious about him, Glaisher tells himself.

"Four miles," he says aloud.

The cold is more intense, —8° F. now the thermometer registers, whilst the air is so dry that the dew-point is —15° F. or 47° F. below the freezing-point of water.

Coxwell throws out more sand and still more. The balloon is soaring higher and higher though there is no sense of movement, only a feeling of floating, but the clouds beneath them seem to be dropping farther down.

The fourth mile had taken 12 minutes; Glaisher glances at his watch as the barometer shows that the fifth mile is reached. It is ten minutes to two—ten minutes it has taken to do this last mile—two minutes faster than the fourth mile.

Death Threatens

Glaisher feels fatigued by his constant attention to his instruments but otherwise is immensely pleased that his breathing is easy, his brain working clearly, and that his limbs move freely.

A fine sense of victory, of achievement, surges in his veins: they are now where no man has ever been before; they are the first to reach

this strange realm with its silence, its beauty and mystery.

Tip out more sand, Coxwell—higher and still higher into the deep blue of the heavens.

Another 1000 feet, 2000 feet and now they both are breathing in short gasps.

On towards the stars they glide. The earth is but a grey, misty flatness far, far beneath them. It seems a thousand miles away, a dream-place, unreal, of no significance. As Glaisher watches, it passes completely from his sight. It is suddenly swallowed up in hazy distance. He looks at the thermometer but the scale is dim and he peers at it. The numbers are blurred. What is wrong? He rubs his eyes, then peers again. Is that a 5 or a 3, or an 8? "My sight is failing," he thinks.

Laboriously he read the barometer. It gave 10·8 inches. A little later it was 9·75 inches (29,000 feet). Then he looked at the hygrometer and his watch. He could read neither.

"Help me with the instruments," he appealed to Coxwell.

But Coxwell was too busy. The balloon had been revolving ever since leaving the earth and in consequence the valve-line had become entangled with the rigging. There is Coxwell up in the ring, trying to release the cord. And still they rise. Glaisher rests his arm upon the

instrument table and waits. His eyes are certainly growing dimmer. His brain orders the arm upon the table to raise the hand and brush it across his eyes. The arm refuses to move. "Raise the other," his brain commands. But the other is powerless also! Glaisher is helpless with limbs paralysed and with blindness creeping on him. What is this coming to me, he asks, this sleep, this deadness? But he is not frightened. There is no pain, no horror, only a heavy drowsiness. He will shout to Coxwell to warn him. No sound comes from his lips, for his tongue and throat muscles will not move.

He shakes himself to cast off this sleep. It is useless. As he looks at the barometer his head falls over sideways. With a great effort he jerks it upright. It falls over again on the right shoulder.

As if from a great distance he hears the voice of Coxwell saying: "Temperature—barometer—observations," and then knows that Coxwell is trying to awaken him out of this overpowering sleep.

"I cannot move now," he thinks.

He tries with a last despairing effort to raise his head, to move his arms, his legs. His brain only is working. He is lost. Darkness descends upon him, complete darkness and the next

moment he crumples up on the floor of the car with his head on the edge.

"This is death," is his last thought as he falls.

Coxwell to the Rescue

Coxwell up in the ring is nearly paralysed with cold. He fumbles with the cord and now notices that his hands are going black, frozen in the dreadful cold. Frost glistens round the neck of the envelope. The clouds are a vast distance beneath him. Will this valve-cord never be untangled? His hands are blacker still and now have lost all power. He glances quickly at Glaisher and sees him crumpled on the floor as if in death.

Was it death? Was he alone in this boundless, silent space? His hands are now frozen and useless. He places his arms on the ring and drops heavily into the car. He wants to reach Glaisher but cannot move forward a step. He must open the valve so that they can descend.

"Hurry, hurry, or it will be too late—pull, pull the valve-cord, pull," his brain commands.

Too late. He cannot raise an arm. A drowsiness is running through him up to his brain. He seizes the cord in his teeth and with the last dregs of his energy pulls. The valve opens.

The balloon almost immediately starts to drop.

Out of a thick darkness Glaisher hears the voice of his companion trying to arouse him: "Do try; now do!"

The darkness lightens. Dimly Glaisher sees the barometer tube, the other instruments, then the form of Coxwell bending over him, then gladness driving the anxiety from Coxwell's face.

He sits upright, stretches himself as if awaking from a deep sleep and says:

"I have been insensible."

"You have," answers Coxwell, "and I too, very nearly."

The first thing Glaisher does when he rises to his feet is to take a pencil and resume his observations!

But he lays it aside as soon as he notices Coxwell's black, frost-bitten hands, and rubs them with brandy until the circulation is restored.

The descent is very rapid, so rapid that it is checked by throwing out sand.

As they come down, strength and sight return to them and gratitude wells up in their hearts at their escape from death.

Not many minutes elapse before they are safely to earth, once again, in a field at Cold Weston just outside the town of Ludlow.

How high had they been?

Glaisher answers that question in his own words: "My last observation," he tells us, "was made at a height of 29,000 feet ($5\frac{1}{2}$ miles); at this time (1 hr. 54 min.) we were ascending at the rate of 1000 feet per minute; and when I resumed observations (that is, after his unconsciousness) we were descending at the rate of 2000 feet per minute. These two positions must be connected, taking into account the period of time between, viz. 13 minutes. And on these considerations the balloon must have attained the height of 36,000 or 37,000 feet."

Again, a very delicate minimum thermometer read 11·9° F. and this would give a height of 37,000 feet.

Mr. Coxwell, on coming from the ring, noticed that the centre of the aneroid barometer, its blue hand, and a rope attached to the car, were all in the same straight line, and this gave a reading of 7 inches, and leads to the same result. Therefore, these independent means all lead to the same height, viz. fully seven miles.

We have seen how altitude affects human beings. How would other forms of life fare in those cold rarefied reaches of the upper air? Glaisher took a cage up with them with six pigeons. The first was thrown out at three

miles." It simply stretched out its wings and dropped as steadily as a piece of paper.

The second released at four miles seemed quite unperturbed at its unwonted surroundings and flew strongly, dropping lower at each circling until it passed out of sight earthward.

The third, thrown out at between four and five miles high, made no efforts to use its wings but dropped straight down like a stone.

On descending, another bird was sent off at four miles; it merely flew around and finally perched on the top of the envelope.

The remaining two were brought down to earth, one being too weak to fly at all for a quarter of an hour, the other being dead.

Of the four pigeons released only one was seen again and that one returned to Wolverhampton two days later.

CHAPTER VIII

Increasing Knowledge

Glaisher's expedition had been most successful from every point of view.

He had reached a height never before attained and returned safely with knowledge that far exceeded his hopes.

Gay-Lussac had stated that the temperature fell 1° F. for every 300 feet of altitude. Now Glaisher's observations disproved this theory. What he found was that there was a decrease of temperature up to 15,000 feet, then a warm current was entered which continued up to 24,000 feet. From 24,000 feet the thermometer fell steadily up to the highest point reached. The same current of warm air was met with on the descent. Up to 14,000 feet there was often a fall of nearly 2° F. for each 300 feet. Beyond the warm current, that is, beyond the 24,000 feet, there was a steady but not entirely regular fall of temperature.

This was a question that would need many more expeditions to solve satisfactorily.

Glaisher had made sure of the truth concerning dew-point. Apart from the cloud areas he had proved conclusively that the higher you went the drier the air became, in other words the dew-point became lower the higher you rose. At heights exceeding 30,000 feet the dew-point was as low as —50° F., that is, 82° F. below the freezing point of water. *Thus the air was exceedingly dry.*

The early adventurers had reasonably imagined that there would be found a powerful charge of electricity somewhere in those thick, immense, angry clouds where the thunder and lightning were born.

Indeed in the first days of Aeronautics that was one of the great dangers that certainly did not daunt the stout hearts but for which they deemed it necessary to be prepared and, if possible, to guard against.

But Glaisher found no terrifying forces. What he found was a positive charge of electricity at lower altitudes which decreased as he ascended, until at 23,000 feet it was too small to measure and then later a negative charge became apparent.

True, he had not tested a heavy threatening thunder-cloud.

He found that the air at that great height of 36,000 feet was exactly the same in composition

as the air at the surface of the earth, that is, it was a mixture of roughly four parts of nitrogen gas to one of oxygen, and a small quantity of carbon dioxide and water vapour. That small amount of carbon dioxide diminished with altitude, however, until at the greatest height reached there was scarcely a trace. There was one great difference, however. The air became thinner and thinner the higher he went. It was this, aggravated by the intense cold, that had produced unconsciousness at 29,000 feet.

The question of winds greatly puzzled Glaisher. Winds blowing from every quarter were encountered, and the changes were of startling rapidity and character. Though there might be a heavy south-west wind at the earth's surface at the moment of starting, it did not follow that that would be the wind at every altitude. Indeed he found that as he ascended, a south-west wind might suddenly change to a west, and a north wind to a north-east or a north-west.

Once or twice he passed up out of a south wind into one due north. Did these observations point to a chaotic condition of air currents? Did the winds obey no laws? Were they actually the fickle, capricious things that poets have so often described them?

Glaisher did not believe so and he determined to examine their nature closely.

Glaisher Sets Off Again

The day had been chosen, the balloon had been partially filled overnight, and Glaisher and Coxwell were impatiently waiting, for there was a thick mist and a heavy N.E. wind.

A 40 miles an hour north-east wind.

One rope only held the balloon to earth and whilst the two aeronauts, standing in the car, were discussing whether they should start or abandon the attempt, the question was suddenly settled for them. There was a savage tug of the wind, a sharp snap as the rope broke, and up shot the balloon. The departure was so sudden that both Coxwell and Glaisher were thrown amongst the instruments, and to the sorrow of Glaisher his Daniell's and Regnault's hygrometers were smashed.

They leapt up to 3000 feet; passed through cumulus clouds, reached 7000 feet; and at 8000 feet a thick fog. At 10,000 feet they were in clear air again and saw the towers of the Crystal Palace.

And now they realized that they were in a north wind. They were moving south. So the wind had changed from north-east to north.

On they went up through another great cloud which was of one temperature throughout; up still to a cold region, through that to a warmer one, and then to a still colder region above. They were now over four miles high, the earth was completely hidden by cloud, and they were anything but sure of their position.

The valve was opened and down they dropped a mile in three minutes. They reached the clouds at 12,000 feet and just as they had broken through, Coxwell exclaimed:

"What's that?"

It was Beachy Head!

They had passed into another wind at some altitude that had carried them south and now they saw in the sea stretched beneath them a very great danger.

"There's not a moment to spare—we must save land* at all risks—leave the instruments!" ordered Coxwell.

With that he seized the valve line, almost hung on it and told Glaisher to do the same. The cord cut their hands but they did not falter. It was a very risky thing to do, but the danger of passing out over the sea had to be met and met boldly.

They were quickly down to a mile and the earth was rushing up to meet them. Two

* An aeronautical expression for "Keep over the land."

rents spread across the envelope. Faster and faster they dropped.

The fields became large, the colour of them brighter, the mounds and hollows clearer. In five seconds the rising ground would hit them.

"Hold on!"

There was a crash. They had landed!

Every instrument was smashed—except one. And that one, to the delight of Glaisher, was the aneroid barometer which had served him so well in his last record flight, and which Coxwell had read when he himself had lain unconscious.

What had been learnt concerning the behaviour of the winds? The clouds of mist and fog had largely spoiled the venture, but the little that had been observed and so forcibly impressed upon them by the accident, sowed the seed of an idea in Glaisher's mind.

The wind had backed from N.E. through N. to N.W. Here was something definite. There had been windless spaces, there had been upward currents, there had been cold, very cold streams, there had been warm streams.

There was mystery here but he had an idea. Most keen and determined was he to get again on the track of the wind.

His friend Mr. Nasmyth, who had also been

occupied in studying winds and the formation of clouds, wrote to him thus:

"The flatness of the under-sides of the clouds during settled weather appears to me to rest on the upper surface of a stratum of air which appears to terminate at the line of the flat bottom of the cloud."

Well, he would see.

On the 11th of July he set off again with Coxwell.

Solving a Mystery

The wind at the start was strong and due east. They reached 24,000 feet and suddenly found themselves in a north wind. Now, was this just chance, just the fickleness of gusty breezes? They ascended therefore another 1000 feet and still the north wind blew; then they dropped down to see if they could find the east wind again. They descended to 2200 feet and there surely enough they found it.

Up they went again, and at 2400 feet passed as before out of the east wind into the north.

So then there was a slab of east wind 2400 feet thick, and above it a slab of north wind.

How thick was that slab? Glaisher asked Coxwell to send the balloon up so that they could find out.

Up they went, and at 5400 feet entered a

N.N.W. current of air. That north wind was 3000 feet thick, then.

Now note the care and the caution of these scientific explorers. Glaisher did not come rushing down to earth with those discoveries. He tested them again and again by dropping down to 2000 feet, then rising again to 3000 feet, 4000, 5000, 6000 feet.

His findings were confirmed. Those three slabs of air moving in different directions did truly exist.

What is more, resting as it were on the top of the slab of east wind were clouds all flat-bottomed as his friend Nasmyth had suggested. Those clouds were in the country of the north wind, but their under-sides were being swept and smoothed out by the east wind beneath.

Glaisher noted that phenomenon of the winds thus:

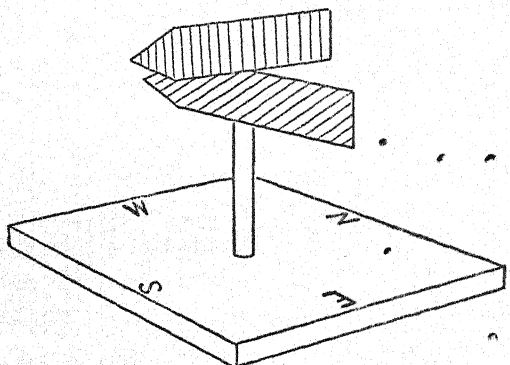
The natural conclusion is that in the air are slabs or layers of winds which move or " back " one above the other in an anti-clockwise direction.

But that conclusion needed testing by a thousand ascents into the mysterious upper air before it could be held as truth.

Glaisher wanted badly to go on up through that N.N.W. layer to find how thick it was.

They started to ascend again, therefore, and reached 6600 feet.

The cirrus and cirro-stratus clouds spread far above them. Glaisher tried to take a photograph of the scene about them, but the light was too poor, for the sun was completely



Model to show the change of Wind Direction with Height

obscured. (An illuminating comment on the speed of photographic plates 70 years ago.)

At that height they were moving S.S.E. Instead of getting above that N.N.W. layer, they decided that they would content themselves by travelling in different directions as they willed, by dropping down in turn into the layers beneath. So they stayed at 6000 feet for a few minutes, and were taken towards Brighton. They then dropped down into the north layer,

and moved due south towards the coast, which soon came into view. Should they cross in this current over to France? They considered this idea for a moment or so, but decided that the wind was too slow to promise success. So they dropped down below 2400 feet into the east wind, and were immediately wafted westward over Arundel, and fields where sheep huddled together in the corners and under trees, in terror at their approach.

A few more miles were traversed, during which all motion, as Glaisher says "seemed transferred to the landscape itself, which appeared when looking one way to be rising and coming towards us, and when looking the other as receding from us."

Two very happy adventurers came to earth that evening—Coxwell with renewed faith in his craft, and Glaisher inspired to new effort by his discovery of the existence of layers of different winds.

CHAPTER IX

Glaisher Finds a New Stream

What an absorbing pursuit was this exploration of the vast aerial space that envelops our whirling globe!

Something exciting was certain to be met with on every expedition.

There was that elusive question of the temperature of the air at different heights—a question of the utmost importance, for upon it depends not only local weather conditions but climate.

On a day in January, 1864, Glaisher and Coxwell set off with the intention of revealing the secrets of the cumulus cloud.

The temperature at the start was 41·5° F., and the wind was S.E.

They expected that the temperature as usual would decline as they ascended. And so it did up to 1300 feet. Then to his surprise Glaisher saw the thermometer rising steadily—a condition nowadays described as an " inversion ".

Just a pocket of warm air floating around, he

thought—we shall soon pass through it. Worth noting, though.

But the thermometer continued to rise—for 300 feet, 500, 1000 feet. It crept up very slowly but steadily right up through 3000 feet when it stood at 45° F.

Three and a half degrees higher than at the earth's surface. Strange, this.

What would happen next? The mercury then fell gradually up to 11,500 feet, at which height it registered 11° F. From 11,500 feet up to 12,000 feet it remained at 11° F.

That region of warmth must certainly be visited again. This was the first time that such a region had been discovered.

Down they came then, and at 11,000 feet entered the snow that was falling much slower than they. The wind was S.S.E. there. That, too, was important. 1000 feet and they dropped through the snow, and came into a region through which a S.S.W. wind was blowing.

Where was that warm slab in which the temperature was $3\frac{1}{2}°$ higher than on earth? Surely enough they soon entered it at 8000 feet. And passing slowly and steadily down through it, they found that it lay 3000 feet thick, sandwiched between an upper and lower layer of cold air. And the wind? Throughout the 3000 feet the wind was south-west.

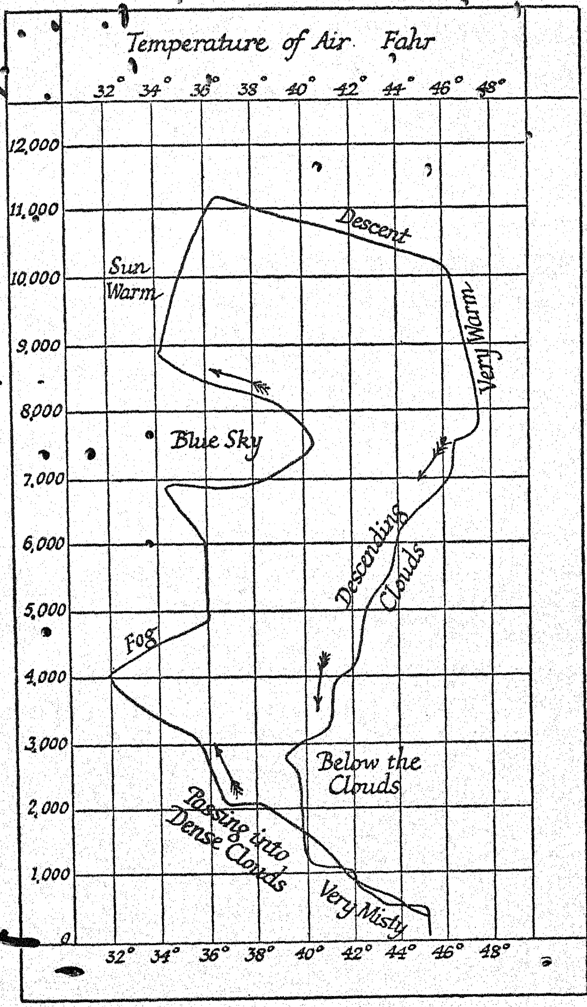
It was that south-west wind that accounted for the warmth. Glaisher immediately thought of the Gulf stream, that great warm current that flows out from the Gulf of Mexico and up the east coast of North America, until it comes under the sway of the south-westerlies. Thence, as the south-westerly drift, it crosses the broad Atlantic to the eastern shores of Europe. The British Isles in particular profit by the immense stores of heat that it is constantly yielding to the air above it. Thus it is that the seaports of Britain, although in the same latitude as the ice-bound coasts of Labrador are never frozen in.

Glaisher was convinced that he had come upon another vital truth. Not only was there a Gulf Stream, but there was a stream of warm air—an aerial south-westerly drift.

Another step towards the truth had been taken.

Glaisher had detected his warm south-westerly drift in January, and, as may be imagined, he was most anxious to know if and where he would find it later on in the year.

In April therefore he made another ascent. There are many gifted with imagination who can share the interest and thrills of adventurers by following along the merest line of their journeyings. For such there is a vivid story in this graph of Glaisher's April adventure.



Temperature of the Air at different heights observed by Glaisher in his Ascent and Descent, 6th April, 1864

Puzzling Signs

As will readily be seen, the temperature at the start was $45\frac{1}{2}°$ F., and there was no decrease at all up to 300 feet—an unusual condition. From 300 feet to 4300 feet it gradually fell to 33° F. Then a warm region was entered which with variations continued up to 7500 feet.

There, then, was his warm stream stretching between 4300 feet and 7500 feet.

In the January ascent, he had come upon it at 1300 feet, and it had persisted up to 3000 feet.

What was to be made of that? The current was there in April, but at a much greater height. He compared, too, the thickness of the two currents.

At 11,000 feet he decided to descend and another surprise was in store for him. The mercury in the thermometer rose through 9° F. in about 1000 feet, thus showing a temperature nearly 1° F. higher than that at the earth's surface. What is more, the mercury continued to rise, until at 7500 feet it stood at 47·5, or nearly two whole degrees higher than at the start.

Why did Glaisher find the warm aerial current at 4300 feet on the ascent and between 11,000 feet and 7500 feet on the descent?

The answer is contained in his own words

describing the adventure. "Our course in this ascent was most remarkable," he says. "After passing over the Thames into Essex, we must have recrossed the river (from Woolwich, that is), and moved in an entirely opposite direction till we approached the earth again, when our direction was the same as at first."

Glaisher had confirmed the existence of the warm aerial current, but he was far from satisfied. No definite scientific statement could be based on two observations alone. A most important truth had been partially revealed: he was determined to go forth again and again until the truth concerning this warm stream of air was completely revealed.

Up he went from the grounds of the Crystal Palace on a clear evening of June. The temperature fell from 62° F. at the start regularly to $51\frac{1}{2}$° F. at 3000 feet.

There was no surprise in that. So far the thermometer had strictly obeyed the law of decrease of temperature with height. A law that is expressed by saying that the "lapse rate" is 1° F. per 300 feet.

But a surprise came later.

Night was creeping on. The balloon was sent down, and at 2000 feet the temperature had risen to 51° F.

From that height he rose again to 3000 feet,

and found that there was no fall of temperature at all.

Also, on descending, instead of a rise in temperature it remained almost unchanged right down to the earth.

This was remarkable, for it suggested that at night the law might be reversed so that at high elevations the air was warmer than at the surface of the earth.

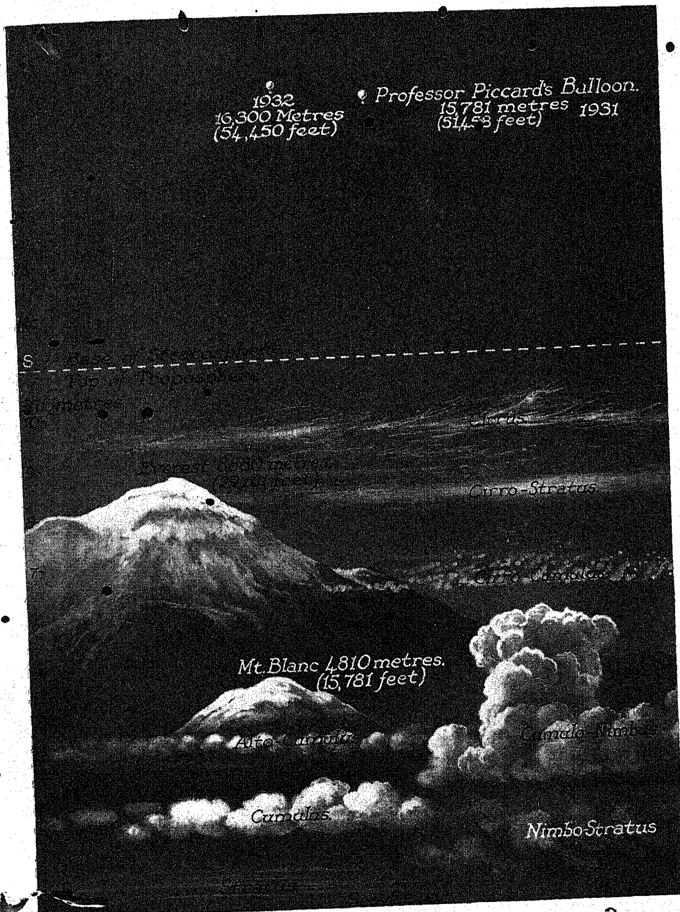
Thus another big question presented itself, and Glaisher realized that hundreds of ascents must be made under every condition of weather, time, and season, before it would be possible to say what was happening in the upper regions of the air, even in the one detail of temperature.

It can be readily understood how slowly knowledge of the upper air was gained.

No sooner did a fact seem established than other elements were met with that contradicted it. Just when the outstretched hand was about to close upon knowledge, that elusive thing would flutter off to another place.

A Dogged Explorer

But Glaisher was a most worthy successor to the long line of pioneers who had risked their lives and given the best of themselves to the splendid task of revealing the mysteries of the air to their fellow men.



PICCARD'S ASCENTS SHOWN DIAGRAMMATICALLY

The altitudes to which Professor Piccard and Dr. Cosyns rose in the stratosphere, and the "great cold belt". The Troposphere (beneath the Stratosphere) is in contact with the Earth's surface and contains water-vapour in suspension, as is shown by the various types of clouds which are formed at different levels. The summits of Mount Everest and Mont Blanc are included for comparison.

Chapter XIII

He had reached a greater height than any man; he had discovered an aerial current flowing over this island that undoubtedly influenced its climate. He had revealed the existence of winds one above another, varying in direction and temperature and speed; he had found that clouds held charges of electricity, that the earth's magnetism diminished as altitude increased. The formation of clouds, of hail, the effect of varying altitudes upon sound, upon the human senses, upon the heat of the sun—all these he had carefully studied and revealed.

With what infinite care and persistence and courage did these adventurers labour!

Defeat, disappointment, danger, could not turn them from their purpose.

Into the vast unknown regions of space, in the frailest of craft that could not even be steered, these fine spirits were laboriously, doggedly, groping their way.

Man in his indomitable striving for the secrets of the universe is magnificent.

Not content with the results of his ascents, Glaisher obtained the valuable assistance of Mons. Giffard, who placed at his disposal a great captive balloon that could ascend to 2000 feet, and whose ascent and descent could be easily regulated.

A large number of observations were carried out by means of this balloon, at different hours of the day and at different seasons, and the results carefully tabulated.

From all these labours came a few grains of knowledge:

The falling temperature with the increase of elevation depends upon the time of the day.

The changes are greatest at mid-day.

There is little change for several hundreds of feet from the earth, on a clear day.

At sunset the decrease of temperature with altitude is at the rate of 1 for every 300 feet.

The *general law* is that there is a continuous decline in temperature with increasing altitude.

Another golden grain of knowledge was gathered by this experiment of Glaisher:

He fixed a dull, blackened-bulb thermometer within a vacuum, so that its bulb projected beyond the car, and so would receive the direct sun's rays.

Another thermometer was placed on the table of the car in the balloon.

Would it not be thought that the first thermometer standing out in the full rays of the sun would show a higher temperature than the other within the car?

It was not so. The reverse was shown. Glaisher repeated the experiment many times

and at various heights, and always he found that the temperature was higher near a body upon which the sun's rays beat, than in free space.

What was to be gathered from this?

There was surely only one deduction.

He was certain that *the sun's beams passed through space without heating it.*

That not until the sun's rays beat upon some substance did they produce warmth.

This was of vital importance, and accounted for the drop in temperature the farther one went from the earth. But, you will argue, the air when the sun is shining is hotter than on a dull sunless day.

That, of course, is true, but it is not the sun that is directly warming the air. It is the earth that is receiving the heat and is throwing it back.

The farther therefore you move from the earth the weaker becomes the radiated heat.

One of the most remarkable discoveries was that strangeness, already mentioned, of the air currents. Glaisher was greatly puzzled by them.

Every time he went up he found currents of air moving in different directions. Sometimes the wind that was blowing upon the earth's surface was the same at 20,000 feet. That

meant a mass of air 20,000 feet thick, moving in one direction. Sometimes there were slabs of moving air only 500 feet thick, and sometimes there was a slab of air moving over another in an entirely opposite direction.

Consider the importance of this. If a warm moist south-westerly layer of air moves over a cold north layer, the water vapour of the upper layer will be condensed into mist or clouds, eventually to change to rain or snow, and probably fall at last to earth.

If the cold layer is moving over the warm, snow might well be produced where the two surfaces meet, but before it could reach the earth, the warm layer would transform it to vapour.

That is what happened when Glaisher came upon snow falling thickly and, dropping down faster, passed out of the storm into the clear sunlight of the warm layer of air.

Glaisher is Awed

Cannot we easily understand and share the fascination of the adventurers in this marvellous mysterious realm?

"Above the clouds," Glaisher says, "the balloon occupies the centre of a vast hollow sphere, we seem to be citizens of the sky, separated from the earth by a barrier which

seems impassable. We can suppose the laws of gravitation are for a time suspended, and in the upper world, to which we seem now to belong, the silence and quiet are so intense that peace and calm seem to reign alone.

"Above our heads rises a noble roof—a vast dome of the deepest blue. In the east may perhaps be seen the tints of the rainbow on the point of vanishing; in the west the sun silvering the edges of broken clouds. Below these light vapours may rise a chain of mountains, the Alps of the sky, rearing themselves one above the other, mountain above mountain, till the highest peaks are coloured by the setting sun. Some of these compact masses look as if ravaged by avalanches or rent by the irresistible movements of glaciers.

"Some clouds seem built up of quartz, or even diamonds; some, like immense cones, boldly rise upwards, others resemble pyramids. These scenes are so varied and so beautiful, that we feel that we could remain for ever to wander above these boundless plains."

All his labours and adventures and observations convinced Glaisher of a great truth, and he expressed it in these fine words;

"Every motion which occurs in our atmosphere is governed by a fixed law. The forces which form winds, clouds, and tempests; the

forces which preside at the grouping of the storms, the birth of soft breezes, the movements of the aerial tides, are just as positive and absolute as those which cause the celestial orbs to revolve in the depths of infinite space."

How true was that pronouncement we shall see in the story of those who took up the trail that Glaisher had so splendidly blazed.

CHAPTER X

The Happy Adventurer

Scientist and Poet

There was Flammarion. He, too, heard the call of the vast aerial ocean, and answered it.

At different hours of the day and night, and at all seasons of the year, this intrepid explorer set out. Nothing escaped his notice; no detail was too small for his attention, and he observed the phenomena of the upper air with the eye both of the scientist and the poet.

"Not even the slightest breath of air is the product of chance," he wrote, "and we may confidently hope to see the day when the causes of the slightest motion shall be known, and when the predictions of weather will be the result of true meteorological science."

He revelled in the beauty that spread about him as he ascended—the green plains delicately shaded by the hand of Nature, the sun-bathed, fleecy clouds, the pearly mistiness of limitless space, the empurpled valleys and snowy caps of cloud mountains, the great inverted bowl of

the sky. And the overpowering majesty of the sombre thunder clouds from which might flash at any moment its swift weapon of lightning—that, too, claimed his admiration.

"Thunder is heard growling beyond," he says, "and zig-zag lightning flashes across that portion of the sky. Around us the sun shines brightly. The sun gilds our balloon with its evening rays, and the aerial skiff glides silently along."

He shouted, and the sound returned as an echo after six seconds. The storm was coming nearer. The balloon seemed to be drawn towards it as if by some magnetic force. The lightning and thunder grew more intense and filled the darkling air with deep sounds that came echoing back, and with blinding flashes.

It was all strange, majestic—beautiful, with a terrifying beauty. The storm was rushing forward as if to engulf the frail craft. Fortunately Flammarion had with him that skilful and experienced aeronaut, M. Eugene Godard.

Already they were on the fringe of the furious storm, and rain pattered on the envelope. To hesitate now would mean disaster. There were two means of escape; one to rise above the storm, the other to descend and land.

Godard chose the latter, and soon they heard the wind shrieking in the tops of the oak-trees

in the Forest of Fontainebleau. With splendid skill the balloon was made to sail over the trees and land safely in the adjacent park.

Flammarion's experiences and observations make a most interesting chapter in the great volume of aerial exploration. His alert mind was ever open to receive the smallest sign and portent.

A cloud of butterflies fluttered round the car when he was at a height of 3281 feet above the earth. Where did they come from? How could such delicate things, that are swept away by the lightest breeze, reach such a height? They flew around as if that was their natural environment. Whilst he was considering this, he noticed the shadow of the balloon. Yesterday, as it travelled over the fields, it was black, circular, and surrounded by a slight penumbra. It was now white and so big that it covered several acres of ground, and seemed to light up the fields as it passed over them. He spent half an hour watching it, and was inclined to believe that the balloon, in the strong direct rays of the sun, was acting as a huge lens.

Rivals in the Clouds

As they were sailing along one day through a broad expanse of cloud which completely hid

the earth, the sun came pouring in as if a great window had suddenly been opened. Flammarion, lost in admiration at the glorious purity of the scene, was startled to see from among the gilded cloud-tops before him, a balloon emerge—a balloon just about the same size as his own, and containing two men. It was so clear that he could see even the cordage, the ropes, and two or three instruments suspended from the rigging.

Flammarion waved his right arm in greeting. One of the figures in the car of the other balloon waved his left arm in an exactly similar manner. Godard then seized the banner, and simultaneously the other figure seized a banner, and they waved to one another.

So clear and real did that other balloon appear that for a second or two, it was impossible to believe it was nothing more than the shadow of themselves upon the whiteness of the clouds.

All around the spectral balloon were concentric circles of different colours—pale blue, yellow, red, violet. Here was another problem, and Flammarion recalled that De Saussure and several other scientists had given an explanation of the strange appearance. They attributed it to the shining of light through crystalline particles of ice, but Flammarion was bound to

reject this, for his balloon was not in an ice zone. He attributed the phenomenon, therefore, to the breaking up of white light by the action of the minute particles (vesicles) of mist that filled the air.

At a height of 7550 feet he hears the bark of a dog from the earth beneath, and the sound of a band playing. He made experiments on sound with the purpose of finding if it travelled upward more readily than downward.

Different sounds have different ranges. At 10,000 feet there was the whistle of a locomotive, but no sound of the train, which, however, was heard at 8200 feet. The bark of a dog penetrated up to 5900 feet, and that, too, was the height at which the report of a gun could be heard, the crowing of a cock, and the ringing of a church-bell.

Once as he was passing over the countryside on the southern side of Paris, to his immense surprise he heard a voice calling: "Come down—come down for lunch." He was at a height of 1700 feet and, looking over the side, he discovered he was over the grounds of a friend who was gazing up and offering an invitation to lunch.

"Cannot stop, thank you," he shouted, but not a word of his answer reached his friend, though the latter's voice had sounded clearly.

Flammarion made 550 observations of the decrease of temperature with altitude, which showed that the decrease is more rapid when the sky is clear. At such times the decrease was, he found, 1° F. for every 320 feet.

The decrease of temperature was more rapid on hot days than on cold, and the temperature of clouds was almost invariably higher than the temperature of the air surrounding them.

Joyous Adventure

Never was there a dull moment on those explorations, never an expedition that did not yield a crop of incidents, entertaining and instructive.

A vegetable hygrometer, which Flammarion had made and mounted on a square foot of white cardboard, slipped out over the side of the car. He leaned out and stretched forth both hands to try to rescue it, and was instantly clutched by Godard and pulled back into the car. That, explained Godard, was a most dangerous thing to do—to sprawl out over the edge of the car thousands of feet above the earth.

Flammarion did not deny it, but he seemed to have none of that fear, that dread of great heights, that assails many people. A perfect contentment at floating above the world and

all the miseries of mankind possessed his heart, and gave a calmness never to be experienced on earth. Giddiness at no time assailed him, but, at times, looking over the car-side at the world, misty and vague beneath, he felt a temptation to throw himself out and sink down through the blue haze—to immerse himself in the great ocean of limpid air around him. That temptation, however, he had no difficulty in resisting.

A curious sight came to him as he passed one day over the confluence of the Marne and the Seine. The water of the Seine is green while that of the Marne is yellowish, and the two do not mix. He saw, therefore, a river of two colours, yellow flowing on the right, with green on the left, and to increase the strange effect, a canal, stretching along the river course, added a third strip of blue.

Then over Paris there was that weird thick cloud, stationary and seemingly pressing down on the city, whilst the sky was a clear blue. There it lay lit up by the sun, oppressive and ominous. It could not be a rain cloud, nor a mist on that warm day. Flammarion had no doubt of it—it was the cloud of dust stirred up by the manifold activities of the great city, and maintained through all the waking hours of the day.

The sight only increased his delight in the

purity and cleanliness of the air through which he was floating, and when, over the open country once more, he heard the call of the quails in the heather beneath him, and the song of a lark soaring towards the sun, he asked himself how he could have lived even for an hour, happily in a crowded city.

"As the sun sank below the western mist," he says, "the heavens around us were lit by a warmer tint, and the entire plain was tinted by its oblique red rays. We heard the watch-dogs of the peasants bark, and sometimes we saw hundreds of people running together under the balloon, thinking it was about to descend into the fields. The sky was delightfully pure, and the air at the surface of the earth absolutely calm. Slowly and gradually we float towards the ground. Cries of 'Come down, come down! we will take you back to Barbizon—dinner is waiting for you', assail us on all sides. We drop a rope, and some 300 people make a rush to seize it—a few broken noses do not appear to check the enthusiasm at all."

Most people imagine that, as the earth is a globe, at a great height it would appear as a huge round ball. Never is this so. Flammarion's description of the earth when viewed from the greatest possible height, agrees with Glaisher's, and with that of all the other aero-

nauts who have ascended far above the clouds.

The earth appears as a vague flatness stretching away to the horizon which seems to come up like the rim of a saucer to give the impression not of a convex but of a concave surface.

"It is," says Flammarion, "like floating between two concave glasses, the sky and the earth, which seem soldered together at our horizon."

A Bottle from the Heavens!

Flammarion made a very interesting experiment at a height of 10,000 feet. Many years since, it had been stated that if a body dropped from a position that is moving, that body would have the same motion, as it fell, as the moving body.

Thus, if you dropped a stone from the masthead of a ship, the stone would not fall straight down and drop at a point behind the mast, but at its foot.

Flammarion then determined to see what happened when he dropped a body from the balloon which was travelling onward, not upward.

He sent a bottle out over the side of the car. Would it be left behind as the balloon travelled onward? Would it, that is, fall straight down, or would it go down in an oblique line?

He watched the bottle turning over and over, and, whistling shrilly, fall rapidly through space, and always it was exactly *beneath* him.

Though the balloon was travelling onward, never did it pass over the bottle. The bottle was dropping fast, but also it was moving on at exactly the same rate as the balloon. This was so until the bottle was swallowed up in the misty depths beneath.

Flammarion, in his enthusiasm for science, had temporarily forgotten the existence of mortals down on the distant earth. To be in receipt of a bottle from the skies would cause the unfortunate mortal more than surprise, even though it were an empty bottle.

At 11,000 feet Flammarion suddenly felt ill. His eyes ached, his ears ached, his mouth and throat became parched. It was the extreme dryness of the air at this point that was affecting him, and he reached for a bottle of water.

When he drew the cork he thought he had made a mistake, for it flew out as if it were champagne instead of water he was opening.

It had been corked at the surface of the earth when the pressure was fifteen pounds to the square inch. Here, at this height, the pressure was only two-thirds of that amount, and so the cork had been shot out.

Strange effects from this reduced pressure of

the air at great altitude are manifest. At 23,000 feet Robertson found that he could plunge his hand into boiling water without feeling the slightest pain. Why was this? The explanation is at once obvious, if we remember that the boiling-point of water depends on the pressure of the air. By boiling we mean the giving off of vapour through all the mass of a liquid. If there is a great pressure upon the surface of the liquid, the vapour cannot make its way out through the liquid. Therefore more heat must be applied. Thus at a great height where the pressure is slight, only a very little heat is required to boil the liquid, so little in fact that the hand could be plunged in without unpleasant consequences.

At even the height of Mont Blanc it would be impossible to cook an egg because the water would boil away at a temperature quite insufficient to " boil " the egg.

Glow-worms in the Sky!

The infinite interest and alertness of mind of these explorers of the air! Flammarion wished to know if the moonlight was really, as it was generally held to be, the purest, whitest, coldest light seen on earth. How would one measure the whiteness of light? Flammarion's method was ingenious. Thousands of feet above the

clouds he watched the coming of the dawn. Presently a soft tint crept upward from the horizon as if to mingle with the moonbeams. Every five minutes he compared the moonlight with the dawn-light.

At 2.45 a.m. the two lights were exactly equal so that he could read a newspaper just as easily when turned either to the moon or to the still hidden sun.

But that proverbial whiteness of the moonlight? When it shines against the light of candle, gas, or lamp, it is so white that the other flames appear almost red. Now, however!

Flammarion turned sheets of white paper first to the moon, then to the dawn, and his photometer showed him a surprising thing; the pure white light of dawn had caused the other to show distinctly yellow!

There should be no light burning in a balloon, for the hydrogen or coal-gas in the envelope is most inflammable. Therefore, Flammarion, when up at night, made his notes by the light of the moon, and once, when the night was dark, with not even the light of the stars, he took up with him a glass vessel containing glow-worms, and with only their weird gleam upon his paper, worked away in the enshrouding blackness of night, ten thousand feet above the earth.

CHAPTER XI

"For Ever Farther—For Ever Higher"

A Night Ascent

In the whole story of aerial exploration there is no more joyously enthusiastic adventurer than Gaston Tissandier who, as we have described in the first chapter, so nearly came to grief when his balloon burst.

Short of death itself nothing could keep him out of the air. His love of adventure was matched only by the intensity of his desire for knowledge, and where could both be satisfied better than in the vast ocean of air that surrounds our earth?

He, like Glaisher, had the fine vision. "If," he says, "we would understand the atmosphere which envelopes our globe, regulates the course of the seasons, affects the whole of life, we must traverse and investigate it throughout its length and breadth and depth, and to do this there must be two kinds of exploration: ascents of long duration, and ascents of great altitude."

Tissandier was overjoyed, therefore, when the French Society of Aerial Navigation decided to make two such voyages successively, with the balloon the *Zenith*.

The first, the flight of duration, was made on the 23rd March, 1875. At twenty minutes past six in the evening the *Zenith* shot up into the air, carrying in the car the aeronauts selected by the Society: Sivel, Crocé-Spinelli, Albert Tissandier (a brother), Jobert, and—as may be expected—Tissandier himself. They had with them 1100 kilogrammes of fine sand ballast, many instruments, and physical and chemical apparatus.

They rose into the air, passing over Paris where thousands of lights scintillated, as Tissandier says, " like constellations in a starry sky ". They passed slowly over the gardens of the Tuileries, over the dome of the Invalides, and soon the vision of the great metropolis disappeared beneath the horizon, to give place to the no less majestic countryside.

The sun threw its last fires upon the distant haze now hanging like vast cloud curtains, darkness came down, and only their Davy lamps lit the night for them.

Having tidied the car and methodically arranged the ballast bags, they were ready for their various duties.

Every moment a Joy

Sivel, to whose energy and indefatigable perseverance and love of science they owed the success of the ascent, occupied himself in determining the direction of their route by means of the compass and an 800 metre length of cord, which, trailing to the earth, swung out always behind the car.

Crocé-Spinelli began his spectroscope experiments. Jobert was busy throwing overboard papers on which were written the records of barometric pressure, of temperature, and of the condition of the sky, at the various positions reached by the *Zenith*. These papers it was hoped, would be picked up by persons below and sent by them to Paris.

Albert Tissandier, the artist, was occupied drawing the aerial landscapes. One notable sketch of his shows the curious spectacle of the deformation of the moon as it appeared above the clouds whose main surface was like a lake. Tissandier, the Happy Warrior, was engaged in passing successively 100 litres of air, by means of an aspirator, into tubes of pumice impregnated with potash, so that the carbon dioxide in the atmosphere would be absorbed and could be later estimated and tested in the laboratory.

It was necessary to note constantly the pressure registered by the barometer whose dial was lit by a Davy lamp, and to record temperature, which during the night fell to 4½ degrees below zero. There was also the wet- and dry-bulb thermometer to attend to in order to find the humidity of the air.

To measure the electric condition, at regular intervals, a copper wire 200 metres long, with a gold-leaf electroscope at the end was lowered over the side of the car.

Their attention, too, was frequently claimed and held by the splendour of the infinite heavens, where the shooting star traced its fiery course; by the earth lit by the moon to a pale silver and which by an illusion had the appearance of an immense concave lens.

When people afterwards asked Tissandier if he did not find the night long and the cold well nigh deadly, all his enthusiasm blazed out in vehement denial:

"Never!" he protested, "just the opposite; the time never flew so rapidly for any of us—no hours have ever been better spent!"

The balloon, thanks to Sivel's skill, maintained a horizontal course between 2000 and 3000 feet, and they knew soon that their hope of a prolonged journey would be realized.

Certain members of the French Society had

provided them with an instrument by which they could estimate their speed. This instrument consisted of a graduated circle about the centre of which could be rotated a sighting rule. The observer, knowing the height of the balloon, sights an object down on the earth and in the path of the craft, 30° below the horizontal.

Looking along the rule he notes the exact time when the object has a depression of 60°. As the balloon travels on, the object passes beneath it and appears to the rear. The observer once more notes the exact instant when it reaches a depression of 60°. A second observer took the time between the readings. The two angles and the altitude were known: then, by the aid of a simple trigonometrical table, the speed of the craft was calculated. Their repeated observations gave them figures that on landing were proved to be very precise.

A Strange Vision

At half-past four in the morning a glorious spectacle greeted their eyes. The moon, which had shone all through the night, was surrounded by a resplendent halo—a circle of fire due to the refraction of the light by the ice spangles floating in the air. As they watched it, it became a circle of shining silver, changed to an ellipse, and then slowly a cross of gleaming

white light stretched its four arms across the moon and there remained, a majestic sign upon the deep azure of the heavens.

The atmosphere at this time had a peculiar aspect; about the earth lay a semi-transparent mist, of about 1500 feet thickness, that, as they watched, dissolved as though to reveal the cross to those on earth.

Cirrus clouds hung suspended high in the heaven, and then moving down to the horizon, formed themselves into a long mountainous chain with snow-white icy peaks. For some minutes the illusion was so complete that they had difficulty in believing they were not actually gazing upon the range of the massive Pyrenees.

The halo with its gleaming cross gradually faded out, the light failed, then glimmered again upon the distant clouds, the earth showed vaguely in the soft light and the sea revealed itself a wondrous pearl in the magic dawning.

With the rising of the sun, the atmosphere, usually dry at their altitude of 6000 feet, suddenly became charged with electricity. The gold leaves of the electroscope suspended at the end of the copper wire had moved apart to a very big angle, but a little later, as they were passing over the Gironde, the leaves closed again. They had passed out of the electrical field as suddenly as they had entered it.

As they followed the course of the river, flashing beneath them in the sunlight, they released at intervals four pigeons. One would not fly off into space but perched on the car-edge craning its neck in obvious hesitation. All four birds, when they did make off, sought the earth in wide circles but not one returned home.

They Find a Secret of the Winds

Beyond the Gironde the wind carried them towards the ocean. Happily some fires burning on the marshy plains beneath them gave off a thick smoke which, they perceived, drifted away to the south-east thus indicating that there was a surface current of air from the north-west which, by descending, they could utilize to carry them away from the sea.

The sun had become very hot and the *Zenith* swelled rapidly, the gas within the envelope dilating and pouring from the aperture in streams into the car.

They rose rapidly to 4000 feet, deciding that it would be risky to pass so near the sea at too low an altitude. Then Sivel pulled on the valve and brought the craft to a standstill, but the sun, acting upon the gas, sent the *Zenith* up once more, and so the see-sawing continued until at last Sivel brought it down

to about 200 feet, into the ground wind that carried it out of danger of the water.

That ground wind was very humid, though the wind from which they had dropped had been almost of an absolute dryness.

As they dropped down from the dry to the humid air, the balloon commenced to rotate and dance, as if on the border of the two winds the air became very agitated. The material of the envelope, always so motionless, now trembled and shuddered. There was evidently at the juncture of the two winds a disturbance of vague, opposing currents, similar to those seen in the gleaming movements of oil upon a surface of water apparently quite still.

As the day progressed they found that the ground wind diminished in height but increased in speed, whilst the upper wind remained uniform. That obviously was the dominating wind, and yet it was unperceived by those on earth, who were aware only of the superficial wind.

For six hours they continued their investigations of those two currents, rising and descending about twenty times as they moved onward. The upper wind drove them to the sea, the lower carried them back landwards.

Crocé-Spinelli, it will be remembered, had worked with his spectroscope, an instrument

with a glass prism through which light from an object passes and is split up into differently coloured and grouped bands, according to the nature of the light. It is an instrument of the greatest importance in scientific analysis and was the means by which that very valuable gas, Helium, was discovered in the vast flames, thousands of miles long, that are for ever issuing from the rim of the sun. It has revealed, too, many secrets of the constitution of matter, and it is by its aid that the structure of stars has been examined and their age and their movements assessed.

Crocé-Spinelli found that when the sun and the moon had been beneath the horizon, his spectroscope showed bands of dense water vapour. As soon as the sun or the moon rose, those bands became fainter and then almost faded right out. It was thus evident that the humidity of the upper regions of the air was very low.

That long-duration flight terminated after nearly twenty-three hours. The landing was made without mishap at Montplaisir, in the Gironde. Sivel threw out the anchor which immediately engaged a weighty piece of earth and held firmly. Scarcely had the adventurers stepped out of the car when a number of shepherds, apparently from nowhere, appeared

hastening towards them across the marshy ground at a great pace on tall stilts, and uttering cries of delight and amazement.

Of that most successful exploring Tissander has said: " Never a minute passed without some new experience, some fresh observation to understand; for, in the atmosphere, so little known, everything is to be considered and pondered, everything is to be learnt."

And then with the stirring motto adopted by the French Society sounding in his mind:

" For ever farther, for ever higher,"

he set about preparing for the second adventure. It was an adventure that brought to him the greatest sorrow of his crowded life.

CHAPTER XII

Death Above the Clouds

Three Tried Companions

For ever higher! The day arrived, Thursday, the 15th April, 1875. At 11.30 in the morning, the three companions, Gaston Tissandier, Sivel, and Crocé-Spinelli stepped into the car of their good craft, the *Zenith*.

Three balloonettes, filled with a mixture of air and oxygen in the proportion of seven to ten, were attached to the ring, and connected to the mouth of each was a rubber tube running down to a flask of aromatic liquid. A mouthpiece was fitted to each flask, and upon this apparatus the explorers would rely for their supply of air when they had reached the rarefied upper regions.

A reversible aspirator filled with petrol, a liquid which would not solidify except in the extremest cold, was hung within the car, and would be turned on at 10,000 feet, so that air

would be passed through the potash tubes prepared for the estimation of the proportion of carbon dioxide in the atmosphere.

Sivel had attached within reach several bags of ballast which would open of themselves when the fine string holding them was cut. He had forgotten nothing, even to the laying of a mattress of straw to break the shock of the landing at the descent. Alas! his mattress was to be of no service to him.

Crocé-Spinelli had brought his beloved spectroscope; and two aneroid barometers, checked in the morning under an air-pump, had been suspended from the car, the first to give the pressure from 0 to 14,000 feet, the other to register it from 14,000 to 30,000 feet.

Close by was hung a thermometer with reddened alcohol (alcohol freezes at —38° C.), maximum and minimum thermometers, and eight barometric tubes in wooden mountings designed to record precisely the maximum height reached by the adventurers.

Within the envelope was suspended a thermometer, a detail of much significance, for, when the outside air was registering a temperature below zero, there was a positive temperature within the envelope.

Labouring Above the Clouds

At the moment of their departure, the clouds cleared from the sun, and a flood of light—emblem of joy and of hope—descended upon them. Their spirits bounded with the craft, and Sivel in his boyish delight shouted: "Now we're off, my friends! What happiness!" and a little later, looking up at the swelling envelope: "Look at her, look how she has filled out. What a lovely thing!"

The envelope had been but partially filled to allow for the distension under the heating action of the sun.

At 10,000 feet, so great was the expansion of the gas that it was pouring down from the gaping mouth of the envelope, and Spinelli noted in his log:

> "Temp. 1° C. Slight pain in my ears. I am a little oppressed. It must be the gas."

On they went up through the clear sunlit air, fully aware of the beauty spread about them though occupied with the various experiments and observations.

At 13,000 feet, the scene was marvellously beautiful and they gazed out upon the azure bowl of the heavens across one arc of which, painted in luminous colours, a great sea of cirrus clouds stretched away to the distant

horizon. An opaline mist then formed about the craft and they were floating now in an ocean of wondrous colour.

At that altitude each respired oxygen, not from necessity, however, but merely to test their apparatus.

For some time Crocé-Spinelli had had his eye glued to the eye-piece of the spectroscope. He suddenly became excited, and in a joyous voice called out:

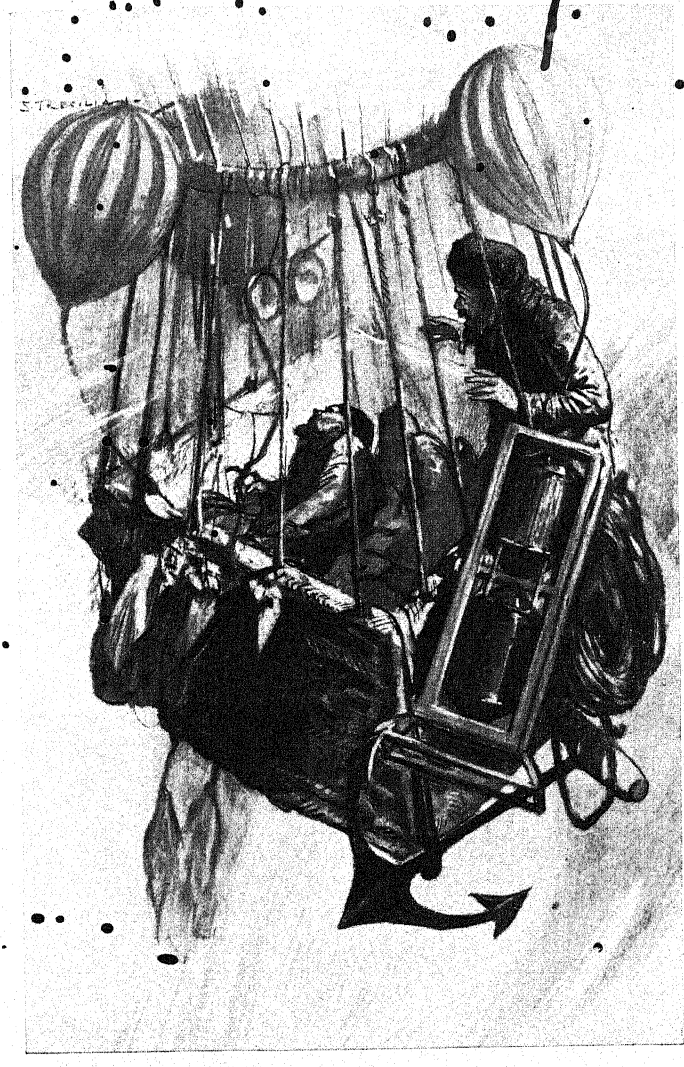
"Here! There's a complete absence of water vapour lines."

So concentrated was he upon what the spectroscope had to tell him that he begged Tissandier to record the thermometer and barometer readings.

As they sped upward a hundred and one tasks claimed their attention. Up to 22,000 feet, thermometer readings had been taken regularly. They showed a progressive diminution up to 11,000 feet, a rise from 11,000 feet to 12,000 feet, and lastly a gradual falling from 12,000 feet to 22,000 feet.

For the first time they determined thoroughly the temperature of the interior of the envelope and the result aroused great interest.

At the centre there was a temperature of 19° F. Close to the top it was 22° F., whilst the air outside was down to 0° F. This was from



TISSANDIER REALIZES THAT HIS TWO COMPANIONS
ARE DEAD

Page 135

15,000 to 16,000 feet. At 17,500 feet, when the surrounding air was down to as low as $-5°$ F., the temperature at the centre was $23°$ F.

At 22,000 feet they were all standing up in the car, Crocé-Spinelli erect and motionless before Tissandier; Sivel, a minute before dull and oppressed, now recovered and quite bright.

"Look, how lovely those cirrus are!" Tissandier said.

The view was indeed magnificent. The cirrus clouds in many lovely colours trailed across the sky and encircled them with a great ring of gleaming silver. They glanced down over the side. What a sight met their eyes—strange, uplifting, engrossing! They were now looking down a deep, deep well, whose sides were of mist and of the cirrus clouds. There at the bottom, through that tunnel of white walls, they saw the flat fields of the earth. It was as if a way through the vastness of the atmosphere had been opened at their feet to lead them back to earth and to their fellows.

The sky above was of a limpid blue; the sun scorched their faces; and yet the coldness of the air began to seize them. Coats and wraps were thrown on, and up they soared,

the cold increasing and penetrating the extra clothing.

The Menace of the Upper Air

They had reached 22,000 feet and a numbness crept over Tissandier. He could just hold his pencil and write mechanically. In a trembling hand, so faint that it could scarcely be read, he wrote:

> "My hands are frozen. I am well. We are going finely. Mist out on the horizon. We are rising. Crocé is gasping. We breathe oxygen. Sivel closes his eyes. Crocé also closes his. Temp. —10° F. Time 1 hr. 20 min. H. 320. Sivel is drowsing.
>
> Time 1 hr. 25 min. Temp. —11° F. H. 300. Sivel drops more ballast."

The last few words were scarcely legible, so weak had Tissandier become.

Sivel, with eyes nearly closed, was quite still as if in deep thought. Then, as if remembering that he wished to go on farther yet, a sudden energy leapt up in him.

"What is the pressure?" he asked.

"300 m.m.," Tissandier told him.

"We've plenty of ballast—shall I throw some more out?" Tissandier answered at once: "Do just what you like."

But Crocé-Spinelli could not speak. All that

he could do was to give a most determined nod of the head. He was not one to turn in the face of danger.

At 24,520 feet then, two of them were frozen to a numbness of mind and body. There, in the paralysing cold and the loneliness of boundless space they saw the immense danger ahead and still they went on.

There were at least six bags of ballast inside the car, and a few hanging outside. Sivel took his knife, cut loose three sacks, and immediately they mounted.

Tissandier moved slowly to the aneroid barometer and just had enough strength to tap it gently. Crocé-Spinelli was sitting, holding in his hand his oxygen flask. His head was on one side as if he were oppressed. Sivel lifted his arm, or tried to, to point upward to the deep blueness of the sky.

Crocé-Spinelli managed to reach the aspirator, detach it, and throw it overboard. Then he threw out a box that had held the potash tubes, and even the instrument coverings.

Only a little farther and they had reached the perilous region where all power to move would be lost, and, worse still, where the cold would no more torture them, where they would become insensitive to pain and utterly indifferent to every danger. They had reached a

point where all they wished for was to go on advancing for ever in that dreamland of profound quietude. They were being lulled to deathly sleep in the vast cradle of the air.

Tissandier made no other entry after noting the pressure of 300 m.m. He knew he could no longer hold the pencil. He stared hard at the barometer and saw that it was falling steadily—it showed 290 m.m. then 280 m.m. How fast they were rising! He wanted to tell them they had reached 26,000 feet, but his tongue would not move, nor his lips. No sound would come. He saw Sivel crumple and slip to the floor of the car. He saw Crocé-Spinelli's head fall forward on his breast. Tissandier tried to move forward to help them. But he could not. Then a sudden blackness shut him in. He closed his eyes and dropped down beside Sivel.

. . . .

A lady was sitting upon the grass in a quiet field, playing with her two young children. There was nobody else to be seen. The place might have belonged to them alone, the sun was shining, they were very happy.

Suddenly there was a shrill hissing in the air above them. It came down upon them with terrific speed. They could see nothing, and in their fright they could not move. Then a few

yards away something hit the earth, there was a sharp, loud crack and tiny particles fell lightly on their hands and faces.

The next day the mystery was solved. A searcher found a box lined with wadding in which the *Zenith's* adventurers had packed the potash tubes, and a scientific instrument cover, likewise belonging to the *Zenith*. What had so nearly destroyed the happiness of the lady was the aspirator that Crocé-Spinelli had seized and thrown overboard just before collapsing, to send them higher still.

. . . .

The Friends are Parted

In the dark reaches of the upper air the *Zenith* is still rising. There is no movement whatsoever in the car. The tiny craft with no hand to guide nor govern it glides on in the mysterious, limitless ocean of space.

Presently it ceases to rise. The icy coldness has shrunk the gas. For some minutes—ten, twelve, fifteen perhaps—it is quite still as if suspended by a thread from the dark vault above. Then it falls gently, falls faster, rushes down.

One of the three stirred. It was Tissandier. He awoke as from an eternal, dreamless sleep. If he could have rubbed his eyes he would

have been able to see where he was, what was happening. But he could not lift a hand. His sight cleared a little and he saw Crocé-Spinelli move. There was the sound of an angry wind all about him. The *Zenith* was rushing down to earth at a frightening speed.

"Throw out ballast," he tried to shout to Crocé-Spinelli, but the words came as a whisper. He closed his eyes and passed again into his dreamless sleep.

It was half-past three when he awoke. The *Zenith* was falling once again rapidly—far too rapidly—and the car was rocking severely.

He got upon his knees and shook Sivel by the arm. There was no response. He shook Crocé-Spinelli's arm and when he released it it fell lifeless to the floor.

Gaston Tissandier was now alone in the blue inverted bowl of the sky and there was an absolute silence.

As he descended, his breathing grew less laboured, his heart beat less fiercely, a little warmth crept back to his frozen limbs. He looked at his companions, but no warmth had come into their cheeks, no warmth would ever come again into their cheeks. They were dead.

As Tissandier came rushing down towards the clouds and saw that neither of the prostrate forms stirred nor opened its eyes, a great fear

struck at his heart. With the realization of that awful silence of death within that other silence of boundless space he shouted. " Sivel! Crocé! Sivel! Crocé!"

Then in a paroxysm of horror and misery shouted and shouted again: " Speak to me, I say! Speak to me!"

At last, after what seemed an eternity of torturing grief, the earth came up to meet him. Distraction had destroyed his great skill and the landing was so rough that the bodies of his dear companions were nearly thrown out of the car.

Two very gallant pioneers had made their last splendid adventure.

" For ever farther, for ever higher ". How magnificently had they striven!

CHAPTER XIII

In the Stratosphere

Failure

Through all the long years of striving after knowledge of the vast aerial sea with which our world is surrounded, only three men had penetrated the intensely cold, soundless, windless Stratosphere.

They were Coxwell and Glaisher in 1864, when Glaisher collapsed and Coxwell was very near exhaustion; and Lieutenant Soucek when, in 1930, he broke the record altitude for aeroplane by reaching 43,166 feet.

And then Professor Piccard, a Belgian physicist, aroused great interest by expressing his intention of ascending to a height of 10 miles.

A crowd of people assembled to see this courageous scientist set off in his strange craft. Their disappointment was only less than his when, everything being ready, and the command to let go was given, nothing at all happened.

The balloon lifted but a few inches, and coming to earth again, stayed there lifeless, whilst one thing after another was tried unsuccessfully, to make it lift.

When a little crowd of spectators got underneath and attempted in vain to give it a start by pushing it up, noble intention had suffered its last indignity.

This first attempt, then, was a dismal failure; instead of ascending ten miles, Professor Piccard had risen about ten inches.

The Second Attempt

Nothing daunted, he had his aerostat redesigned, and on 27th May, 1931, he and his companion, M. Kipfer, soared up from Augsburg, Bavaria, and in a short time were beyond the sight of those who gathered to watch the start.

Steadily they climbed through the Troposphere, up beyond the altitudes of Tissandier, of Gay-Lussac, of Glaisher—thousands of feet into the fearful cold of the Stratosphere.

But they were not cold. On the contrary, they were well-nigh overcome by the heat of their sealed cabin which, being painted black, was absorbing most of the direct waves of heat from the sun. A big mistake had been made in painting the cabin black.

The sun's heat-waves, as you know, pass through the air without heating it. That is why the upper regions of the air, though closer to the sun, are so cold. But when a body is in the path of those rays, it absorbs some of them, and then gives out heat. Hence the warmth of the air near the earth.

Now, the cabin would have been warmed in any case, but its blackened surface allowed the intense heat-rays to be absorbed. Only a few were reflected. In consequence, when they had reached the region of intense cold, and their thermometers registered several degrees below freezing-point, they, in their cabin, were perspiring painfully in the oppressive heat.

A good reflector, as you will understand, is a bad radiator.

A bad reflector is a good radiator.

A good radiator is a good absorber.

Their position became perilous when, at 9¼ miles above the earth, through some simple mechanical defect, the valve became jammed and they found themselves suspended helpless and beyond all human aid, in the deep blue of boundless space, whilst every minute their supply of oxygen, already low, was fast dwindling.

The balloon, invisible to the naked eye, had been observed through powerful field-glasses,

a dim pin-head in the vast blue cushion of the sky.

The Old Craft and the New

An aeroplane, another and another, took off from various points and climbed towards the far-distant craft, drifting slowly and steadily away. The planes soon became specks, and vanished and appeared again still more dimly, till they, too, passed beyond the range of human eye.

What a strangely thrilling circumstance was here—the most modern type of aerial craft endeavouring to carry aid to the oldest. Not that the planes had any hope of reaching the immense altitude of the balloon. In fact, they attained their ceiling many thousands of feet beneath, and then, circling at this height, the pilots watched intently for any sign of life in the little cabin suspended beneath the great envelope of the balloon.

There was no movement whatsoever—no signal from within. The sombre sphere in its very hue was symbolic of death, and death, too, was in the stillness and calm of that deep, deep blueness.

The pilots circled and circled, but there was no lessening of the distance between them and the balloon. The sun was sinking, they were

moving towards the mountains; there was no sign of life above them, and so they returned to their aerodromes, fearing that tragedy was drifting there across the sky.

But with the setting of the sun came the coolness of the evening and salvation to the two adventurers. The fall in temperature diminished the lifting power of the balloon and brought it down. It glided down towards the peaks of the Gross Gurgl Ferner Glacier in the Oetzwald Tyrol, and finally came to rest upon a glacier edge whence the courageous Professor Piccard and M. Kipfer, both exhausted by the manifold dangers and fatigues of the great adventure, were a little later rescued.

Splendid Achievement

The imagination of the whole world had been stirred by that perilous exploit and thus, when in the following year it was known that Professor Piccard, this time with M. Max Cosyns, intended to make an ascent to an even greater distance into the Stratosphere, the adventure was awaited with an interest that deepened to fascination as the appointed day approached.

Here, indeed, was a splendid enterprise, fraught with danger, with interest, with mystery. For it was in research of the Cosmic

Rays that the expedition had been chiefly planned, and of those rays and their amazing powers people had but a very vague idea.

Rays of light they knew, and X-rays, and waves of electricity, of heat, of colour, but what of these Cosmic Rays that could, it was said, penetrate many feet of lead. Whence did they come? What was their effect upon the earth, upon human life? Did they bring strength and health, as the sun's rays, or were they destructive of life? Above all, what would their effect be upon the adventurers?

What new secret of the universe was about to be revealed?

It was indomitable man with his hand once again upon the veil of the Unknown, and the world was thrilled.

The aerodrome at Dubendorf, near the Swiss town of Zurich, presented a strange sight on the night of 18th August, 1932. Great numbers of people, estimated at some 30,000, had invaded Dubendorf, and many were lying asleep through the night, on the grass close by, wrapped in their overcoats. All the roads were streams of motor-cars, cycles, pedestrians. The moon threw long shadows. Within the aerodrome was the immense balloon dancing in the beams of powerful searchlights, as if impatient to be off.

But Professor Piccard was waiting for the sun to rise and warm the atmosphere, and he stood chatting with a crowd of journalists, telling them that he considered the prospects of a successful journey excellent, and that if the strong wind of the upper air caught him, he might be taken across the Mediterranean and dropped into Africa.

Then the dawn light came struggling with the moonbeams, the Professor kissed his wife and children good-bye, adjusted his parachute and, having stored away a rucksack and a little Alpine equipment, in case he was brought down again among the mountains, followed Cosyns into the gondola.

This gondola, only six feet two inches in diameter, is an air-tight, many-windowed, aluminium sphere fitted with scientific instruments, oxygen apparatus, and wireless installation, and suspended beneath the enormous envelope by a number of wires of the finest steel. If these should snap, if the oxygen supply became exhausted, if the envelope should burst, if they should be overcome in the rarefied air of those vast heights, if——

There were a hundred possibilities of disaster, and well the adventurers knew them, but the last glimpse of those nearest was of two faces wearing a quiet smile of unconcern.

Almost at the last moment, messages of good wishes and hopes for success arrived from the King of the Belgians, and from many world-famous scientists.

True to the predictions of the meteorologists, who, be it noted, base their weather predictions upon the knowledge accumulated by the long line of aerial explorers whose story we have been telling, the sun rose in a cloudless sky.

The moment had arrived. A few brisk orders were given, the holding ropes were released, and to the cheers and shouts of encouragement from the thousands around, the giant balloon smoothly and slowly lifted its tiny globe and carried it up and away. The sun shone upon the upturned faces, and upon the receding balloon, lighting it to a gleaming silver.

Such a spectacle of a most daring adventure in search of knowledge is rarely seen, and, in the minds of the watchers, there mingled admiration and pride and awe.

Insignificant man set on a planet in the mysterious universe. Godlike man in his dogged, fearless pursuit of knowledge.

The balloon, inflated to only about one-seventh of its capacity to allow for expansion of the gas as its temperature increased and the pressure of the surrounding air fell, glided up

until at last it became spherical. On it went, on and on, growing smaller and smaller, till at last it was a pin-point which seemed suddenly to pierce the blue vault of the sky and disappear.

Then for some hours there was silence.

. . . .

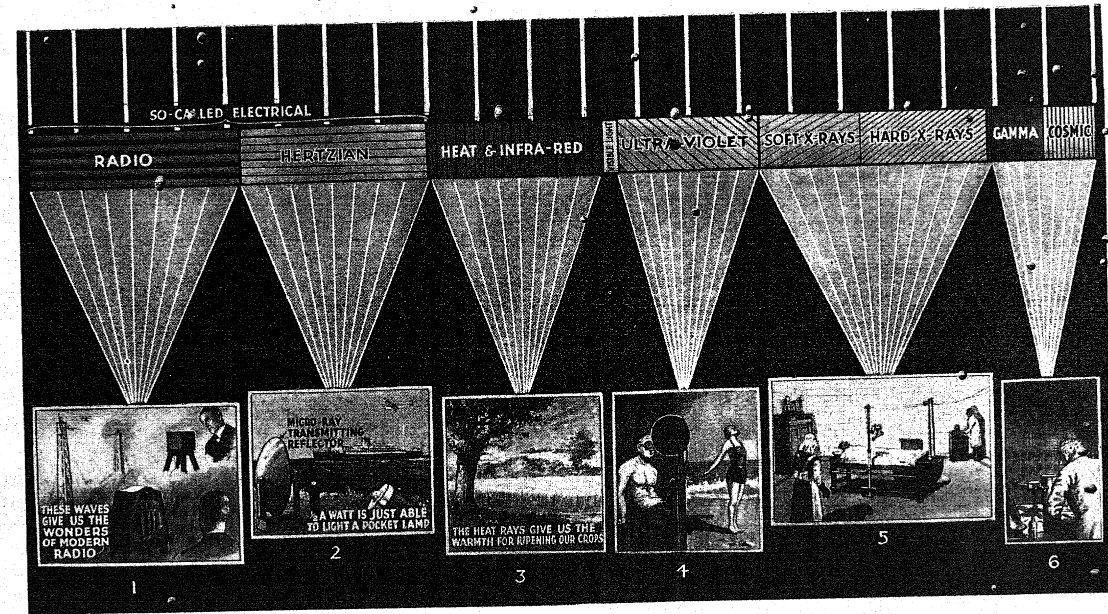
In Search of the Mysterious Cosmic Rays

Within the cabin, the Professor and M. Cosyns were busily employed with their instruments. Many experiments and observations were to be made, but the question that chiefly occupied their minds concerned the cosmic rays.

These rays had been examined at the earth's surface, but since it was discovered that they did not proceed from the sun, scientists were agreed that much better results would be obtained were the investigations conducted at a great altitude free from all interferences.

The cosmic rays occupy the highest division on the great scale of wave-produced energy.

What exactly does that mean? Think for a moment of the keyboard of a piano. It is divided into seven octaves, each octave consisting of eight notes. On the left of that keyboard are the bass octaves, deep in sound, and as you move to the right, the notes rise in pitch, that is, become higher in sound.



"THE KEYBOARD OF THE UNIVERSE"

The complete range of Rays, so far as they are at present known, showing the uses to which man has put them. (1) The Radio waves come at the extreme left of the scale, followed by the Ultra-short waves (2), which permit telephony between England and France, using only half a watt power. The Ultra-violet rays (4) can be artificially produced for healing and therapeutic purposes, while the X-rays (5) are both medically and commercially employed. The Gamma rays (6) are also used in medicine and some of the arts, but no use is yet made of the Cosmic rays, whose nature and properties scientists are still exploring.

Now Nature, too, has a keyboard, a vast keyboard of at least seventy-three octaves.

On the left of it are the Hertzian waves of electricity, waves discovered and produced by the scientist Hertz, and used in "wireless"; next to those octaves come the waves of electricity; they pass into the heat waves, and beyond them again are the light waves (our sunlight). Farther to the right still, that light octave merges into the X-ray octave, and that into the Gamma-ray octave, and finally right at the top of the scale comes the octave or octaves, may be, of the cosmic rays.

A glance at the picture will make this clear.

Why are the octaves of a piano arranged in the order they are?

The answer is, they place themselves in position. The notes gradually increase in pitch. The wire producing each note vibrates faster than the one immediately below it. The top note of any piano-octave has a vibration-rate exactly twice as great as the bottom note of that octave.

In the same way, on the great keyboard of the universe, the Hertzian waves have a vibration-rate (frequency) less than the waves of the next octave—heat.

Again, just as the top notes of a piano are

stronger, more piercing, more penetrating, than the lower notes, so the top "notes" of the Universal Wave-scale are more powerful than the lower.

We well know that X-rays will penetrate solid matter. But the cosmic rays, the most powerful rays yet discovered, will penetrate deeper than any into matter—they will actually pass through ten feet of lead.

A Great Experiment

We have said that the cosmic rays have been tested upon the surface of the earth, and one experiment with them vividly illustrates not only their marvellous power, but the infinite care and ingenuity of the scientist in his work.

The instrument used to detect and measure the Cosmic Rays is the Electroscope. This, being extremely sensitive, is affected by other rays, and it was required to find the penetrative power of the Cosmic Ray.

Lead would make an excellent test, but lead, in sufficient mass, would be awkward to employ. Therefore water was selected.

Now, in ordinary water—the water of rivers and lakes—there is always to be found a certain quantity of elements that emit rays of energy, such being known as radio-active elements.

Where was absolutely pure water of sufficient depth to be found? A lake was chosen, 9120 feet high in the mountains, above the snow-line, so that nothing but pure snow-water fed it.

There the electroscope was taken and lowered into the lake depths, and there it was found that the Cosmic Rays, after penetrating 800 feet, were still able to act upon the leaves of the instrument.

Do we not all know the marvellous power of the "wireless" waves that come to our sets unchecked across mountain and ocean?

The Cosmic Rays are very much more potent. Their effect upon human life is not yet known, but Professor Jeans thinks that they destroy millions of atoms in our bodies every second.

Is it their function to destroy or to create?

Some scientists hold that it is the Cosmic Ray that is building up the universe, as it decays; that star-dust caught in a stream of Cosmic Rays is driven across the millions of miles of the ether until somewhere a cloud is formed. The particles of that cloud are pressed together into a mass, electro-magnetic energy is generated, the mass becomes heated, glows, burns to a white heat, and there, in the infinite cold of outer space a new star is born.

Were not Professor Piccard and M. Cosyns, moving across the sky in their little sealed cabin, on a magnificent quest?

. . . .

It was at 5.5 a.m. by Swiss time that their balloon had floated away. It was at 8.32 a.m. that the vessel was seen moving slowly at an immense height, over the Bernina region of the Swiss Alps. Later, from the favourable points of Davos, and the Corviglia Hut in the Engadine, anxious watchers just made it out passing eastward.

The first wireless message from the balloon was then received: "All right. Observations good. Altitude 14 to 15 kilometres (49,500 feet).

A little later, a second message came: "Are going in the direction of Merano (N. Italy). Are half-way."

With this indication of direction, at 10 o'clock it was sighted above Saint Anton, in Austria, and was seen to be moving southward at a speed estimated at 25 miles an hour.

Piccard's Thrilling Story

How had the two adventurers fared—what exactly had they been doing?

The story could not be better told than by the Professor's own Log:

5.15 a.m. We are away. The balloon is not

climbing properly, so we have to drop some ballast. Closed the sphere on reaching an altitude of 4950 feet.

5.26. Glorious sunrise. We can hear the drone of Mittelholtzer's aeroplane which is approaching us.

5.34. We are now in brilliant daylight, and Cosyns begins his experiments in connexion with the Cosmic Rays.

5.43. We have now reached a height of 5280 feet. Lucerne and the Rigi stretch out before us. We now seal up the nacelle (gondola), and the balloon being hermetically closed, we are perspiring profusely. The atmosphere within the nacelle is extremely oppressive, owing to the expansion of the oxygen.

5.57. We have now reached a point 28,050 feet above the level of the sea.

6.15. The view around us is magnificent. There is Glärnish, and there before us is the Silberhorn, and the Eastern Alps, which I climbed as a young mountaineer fifteen years ago.

6.17. The temperature has dropped to 4 degrees Centigrade, almost freezing-point. The gas in the balloon is expanding, with the result that the balloon is now completely spherical.

7.07. I am sorry that my work prevents me from revelling in the glorious view around me. Besides time forbids me to look round.

7.42. We release some more ballast.

8.42. We come in sight of the Obergurgl Glacier. What memories that brings back of last year's ascent when we came down on that very sheet of ice. Cosyns is working very well.

11.10. We are now sailing over the Engadine.

11.50. We have only 20 sacks of ballast left, and we decide that the time has come for us to prepare to come down in Italy.

12 noon. We are just opening the valve releasing the hydrogen in the balloon. This is our first release of gas.

12.12 p.m. We have reached an altitude of 54,450 feet. All human records broken. Intensely cold. The thermometer shows a temperature of 15 degrees Centigrade below zero. We are suffering intensely. We release more gas.

12.18. We are now northward of Lake Garda. Italy is a gracious land; and we remember suddenly that we have brought with us neither identity cards nor passports.

12.29. We release more hydrogen. We are dropping at the rate of six feet a second. That is quite satisfactory.

1.05. We are dropping rapidly still. We notice snow beneath us. Our valves are functioning well, but the sun continues to dilate our gas.

1.24. Owing to this dilation the balloon has started climbing again, so we have to release some more hydrogen. Ah, now she is dropping! We are going down at the rate of ten feet a second. This is very good, but we must avoid hitting a mountain.

2.08. We have now come down to 40,590 feet, and we are entering the troposphere.

3.28. We are dropping at the rate of ten feet a second. We are now at a height of 21,450 feet.

3.55. I open our porthole again, and I can see that we are descending on a broad plain. I can see before me the wide expanse of Lake Garda. Not a ripple breaks the surface. Clearly there is no wind.

5.0. We shall be on terra firma again in one minute.

"In brilliant daylight," wrote Professor Piccard, at 5.34 a.m. Would the daylight be more, or less, brilliant than at the surface of the

earth? Would it become more intense the higher they ascended?

Not a few would consider the question too obvious. Nearer the source of light, they would reason, the more intense that light.

Actually that is not so. Something else enters in—the consideration of how light travels and how it is scattered.

Light travels in waves, and when those waves reach the earth's atmosphere, the shorter of them, those, that is, that bring the blue light, are scattered by the particles of dust in the air, and by the particles of the air itself.

The result of this is the blue appearance of the sky above us. The sky is not really blue, but is made to appear so by all the blue light rays that are being scattered. When the rays of the sun penetrate the thicker air close to the earth, they meet larger particles of matter and of moisture which scatter every ray, the long and the short, the rays of yellow, orange, green, blue, indigo, violet—all the colours, that is, that together make white light. Therefore as Piccard ascended he passed into bluer and bluer air, and above him stretched a canopy of deep blue, so dark that here and there stars shone against it in the light of day.

Higher yet beyond the Stratosphere, beyond the next stratum, where the temperature rises,

right out in the outer regions of space there would be a great darkness. Out of the direct beams of the sun there would be darkness.

At 28,050 feet, Piccard speaks of the magnificence of the view about them, and higher still, it is with difficulty that he forces himself away from the window to concentrate on his instruments. There is no vision in the world so gloriously lovely as that presented at these great altitudes, and he thinks of the time when the ordinary aerial routes will cut across the Stratosphere, and of the immense joy of the travellers as all this beauty fills their eyes.

Air routes in the Stratosphere? Air routes at 50,000 feet? Decidedly, and at a not too distant time, as will be shown later.

A very good idea of the difficulties and dangers of such an ascent is obtained by attention to the Professor's remarks concerning ballast, gas, speed of descent, the swelling of the balloon. Many balloons have burst at high altitudes by reason of the expansion of the gas within the envelope caused by the heat of the sun's direct rays; shortage of ballast has caused many disastrous landings, and it is necessary to retain sufficient right to the end; the speed of descent must be closely watched and regulated, for the hydrogen gas cannot be replaced.

The first release of gas was made at noon,

nearly seven hours after the start, but ballast of lead dust had been dropped at several altitudes. By these two means alone is the balloon controlled. Although the valves were functioning perfectly, at 1.24 p.m. the sun was heating the gas to such an extent that the balloon commenced to ascend again; and it must not be forgotten that time, and the action of unexpected wind stratum, and the changing temperature of the air, are factors of the descent that add to the explorers' difficulties.

At 4 p.m. the balloon was over Desezano, the training school of the Italian Schneider Trophy team, and high-speed planes put off, climbed to the balloon and, circling about it, conducted it down.

The landing was made at 5.10 p.m. close to the hamlet of Pille di Castellaro di Lagusello, about 20 miles south of Desenzano. A very great scientific achievement might easily have been ruined, for as they came down to earth Professor Piccard shouted an order which the Italian peasants misunderstood. Instead of holding on to the landing ropes, they released them. The balloon sprang up to a height of 150 feet, and then dropped heavily to earth. The adventurers were roughly shaken, but their great fear was for their instruments, lest they should be thrown out of adjustment, and

their registerings disturbed. Fortunately, no damage was done to the scientific apparatus.

So great was the change in temperature and pressure that when Professor Piccard and M. Cosyns stepped from the gondola they collapsed and lay panting for some minutes.

On recovering, their first care was for those who, through the whole twelve hours of the adventure, had borne a very heavy burden—Cosyn's mother, and Piccard's wife—and to each was dispatched a telegram telling of the successful journey and the safe return.

A splendid fame had been won by the two explorers, and messages of congratulation and admiration poured in from every country. Science had been exalted in the eyes of the world.

Professor Piccard was satisfied with the results of the expedition—so completely satisfied that, though he could have risen to an even greater altitude, there was no need to do so.

They had commenced experiments on the Cosmic Rays at 3000 metres, and continued uninterruptedly to their greatest height. That height had been reached in about three hours, so that they had been cruising in the mysterious Stratosphere for several hours.

So cold is it there that the thermometer fell to $-36°$ Centigrade; so beautiful was the

prospect that the Professor could not resist the temptation to leave his work and gaze upon the grandeur and loveliness of the scene that lay about them.

There is no rain there ever; there is no snow, no ice, no mist. All the air is always clear and blue. There are no winds except of the gentlest, and they are always horizontal. It is a calm, clear, infinitely cold region, beneath which the earth and cloudland lie bathed in glorious colours. And no sound breaks the utter silence.

How long will it be before the Stratospheric plane that is now under construction will carry its passengers through this wonderful region, at the rate of 1000 miles an hour?

CHAPTER XIV

The Aeroplane Reaches The Stratosphere

The Aeroplane follows the Trail

The balloon has had a long start in the race to the upper air and leads by thousands of feet. But its supremacy in altitude work is not unchallenged.

A number of aeroplane pilots have attempted to follow the track of Glaisher and of Piccard across the border of the Troposphere into the terribly cold region of the Stratosphere, and several have succeeded.

There was Lieutenant Appollo Soucek, of the U.S.A. Navy, who reached the height of 43,166 feet, or nearly $8\frac{1}{4}$ miles. This airman, America's premier altitude flier, set up a world's altitude record for sea-planes with a height of 38,560 feet, and for land-planes with 39,140 feet, in 1929.

He was not left long in possession of his fine distinction, for only seventeen days later, the German, W. Neuenhofen, climbed to 41,795 feet in a land-plane.

On 4th June, 1930, Soucek took off from the Naval Air-Station at Anacostia, D.C., and climbed up through the Stratosphere in his Wright Apache to 43,166 feet.

He sought the upper air, not as a meteorologist, but as an exponent of altitude flying, and therefore made no purely scientific observations.

The last few thousand feet of his climb were beset with dangers and difficulties. His controls became more and more " soggy " (ineffective), for there was but little air upon which to bite, his engine power fell away, and there was a darkness about him upon which, as upon a deep azure curtain, a planet now and again glinted.

So far, it will be noted, English planes had not figured in the race to the upper air.

Indeed, a survey of scientific and mechanical development and progress shows that in a great many instances, England is the last to enter the field, and then walks off with all the prizes.

It is England's way.

A World's Record is Made

America and Germany alternately shared the honours and then came Flight-Lieut. Cyril F. Uwins, chief test-pilot of the Bristol Aeroplane Company, in his Vickers-Vespa, fitted with the new Bristol " Pegasus " engine.

When he took off from the Filton Aero-

drome at Bristol, at 1 p.m. on 16th September, 1932, the atmosphere was misty and still. He hoped, as he climbed, to break through into clearer air, but if anything the mist thickened, and though he was not actually flying blind, for the greater part of the adventure the earth was hidden from him.

In this grey, objectless environment there was no sense of speed. The drone of the engine, his altimeter before him on the instrument-board, and the rush of air about his head made for him the consciousness of progress.

The engine purred its way rhythmically up through the lower strata, reached the colder, more rarefied regions, and did not falter. Minute after minute, the Pegasus drove on through the ever deepening blue of space. 25,000 feet, 30,000, 35,000, 40,000 and still the engine was running smoothly and with power.

This was beyond the height where Glaisher, in his balloon, had so nearly been overwhelmed by the cold and the rarefied air.

Science nowadays provides protection to the pilot against both these dangers, but at the same time any failure of the appliances on which he relies involves him in new dangers.

Danger in the Upper Air

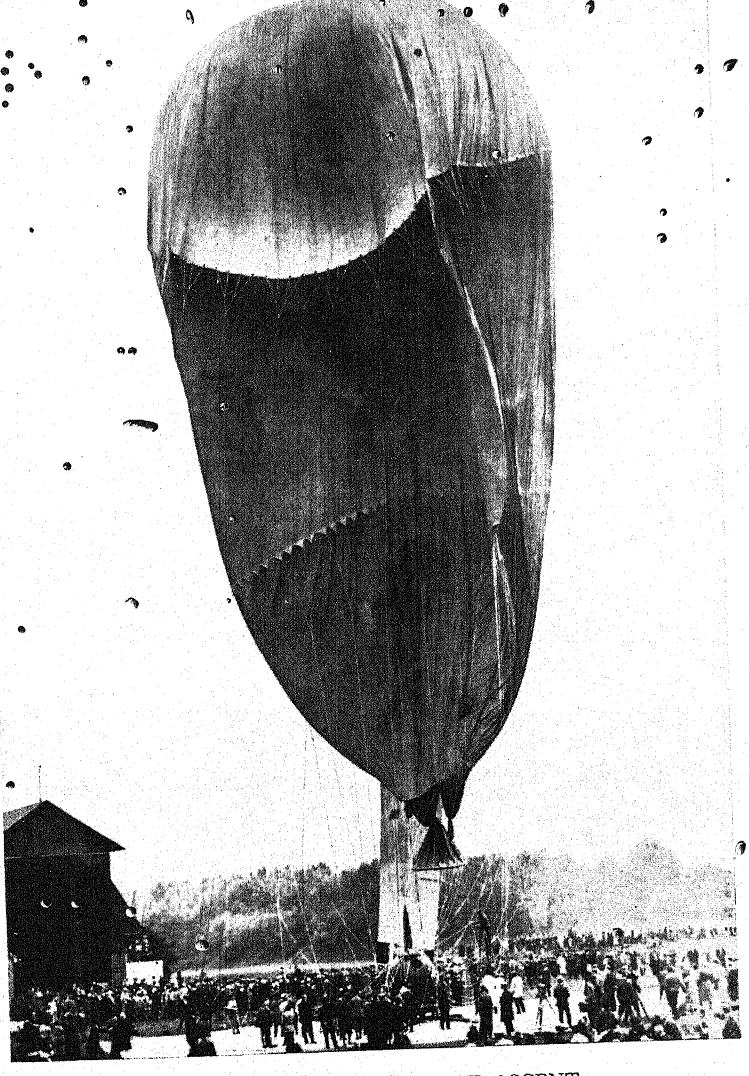
Thus. the modern oxygen apparatus enables

a pilot to reach greater heights than the pioneers of old, and thereby encourages him to attain a position of greater danger. If the oxygen should fail, by reason of his more exposed position he is probably doomed.

This possibility of disaster was exemplified in the flight over the mysterious summit of Mount Everest, by Flight-Lieutenant D. F. McIntyre in the Westland Wallace aeroplane, with Mr. S. R. Bonnett as expert aerial photographer.

At 10,000 feet they had tested their electrical heating sets, and their oxygen apparatus. All had gone well as they climbed slowly and steadily into the glorious scenery of the mountain peaks. As they went over the top of Everest, Mr. Bonnett stood up with head and shoulders out of the cockpit, the better to use his camera. Suddenly a buzzing sounded in his ears, as if an engine were running within his brain; a faintness came upon him, and then a violent pain seized him in the stomach. He sank down into the cockpit, incapable of making the slightest movement without great effort.

Then it was that he noticed a crack in the tube leading from the oxygen apparatus to his mask. It is probable that as he stood up to secure pictures of the entrancing scene before him, in his excitement he trod on the oxygen tube and caused a leakage of the precious gas.



PROFESSOR PICCARD'S FIRST ASCENT

The huge balloon in which Professor Piccard made his first ascent, at Augsburg, May 27, 1931. The spherical " cabin ", suspended from the gas envelope, is resting on the ground

He bound his handkerchief around the crack and shortly recovered, though the medical examination of the four explorers on landing (Colonel Blacker and Squadron-Leader Lord Clydesdale had been over the summit in the second plane, the Houston-Westland) revealed that Mr. Bonnett had suffered by far the greatest strain.

Science, too, has provided the adventurer with electrically heated clothes, but again there is a new danger—the danger of fire.

A friend of the writers was on an altitude flight recently, and had reached 20,000 feet when a faint smell of burning came to him. There can be no more dread menace to an airman than fire. It will be recalled how during the War, before the advent of the parachute, pilots by the score leapt from their planes, preferring to be smashed rather than burnt to death.

The smell of burning grew stronger, faded, then came again. There was trouble somewhere and it was increasing, but he could not locate it. He therefore turned the nose of his machine down, and scurried back to earth. Before he reached it he knew what had happened—an electric wire had shorted and his clothes were on fire!

At 40,000 feet then, there are many thoughts

of danger to come knocking on the brain. There are also many inspiring thoughts of fine achievement to send the adventurer onward.

Uwins was within about 3000 feet of Soucek's record, and still his engine was pulling splendidly. On he went. His altimeter registered 43,900 feet. If this figure could be trusted he had captured the World's Altitude Record.

Glorious moment!

On his downward flight to earth he escaped a very great danger. His petrol gave out and had there been a heavy wind in the lower regions he might easily have been swept away over the Bristol Channel. As it was, he landed safely at Evesham after having been two hours in the air.

Although it was generally thought and hoped that a new world's record had been set up, not until official verification had been made could the honour be claimed.

Uwins's two sealed barographs were forwarded to the National Physical Laboratory for examination, and there the charts were found to register an altitude of 43,976 feet. This figure and full proof of its authenticity was submitted to the International Aeronautic Federation by whom it was acknowledged and adopted as the World's Altitude Record for Aeroplanes.

Honour Where it is Due

Uwins insisted that his splendid achievement was due to the designers and the engineers who had provided him with his superb craft. He would take little or no credit to himself, as if all that he had done was as easy as making an ordinary test flight.

His fine tribute to the designers and engineers of the famous firm of Vickers was certainly richly deserved.

If we consider first the machine we find that the aerodynamical and physical limits imposed by the new conditions require considerable changes to be introduced into the design both of engine and plane. The density and pressure of the air fall rapidly with increasing height, and at as low a level as 15,000 feet (three miles) the pressure is halved. In other words a barometer reading 30 inches at the surface of the earth, would register but 15 inches at 15,000 feet.

An aeroplane depends for its lift or support upon the reaction of the mass of air deflected downwards by its wings.

With a steadily diminishing density of air it is inevitable that the lifting power of the wings must decrease.

For the same reason the efficiency of all the control surfaces—rudder, elevators, fin and

ailerons—will become less as the machine climbs higher into the thinner air.

What can the designer do to counterbalance, in some degree, these unavoidable losses? Much research conducted by the aid of the wind-tunnel and other devices has established the fact that the lift obtainable from various wing sections or profiles varies to a great extent. So the designer is led to continue his search for such a wing section as will give him the greatest lift for the least expenditure of power. Another method is to increase the area of the lifting surfaces that they may react on larger masses of the less dense air.

Another aerodynamic difficulty is also experienced. The screw propeller, upon which the aeroplane depends for its motion when climbing or flying horizontally, will find little air for its blades to bite on in the rarefied regions of the upper air. Once again a specially designed air screw of greater diameter than is customarily used will be needed. Within limits a higher speed of revolution will be an advantage, but here a new difficulty arises, since increased diameters and speeds will entail much higher tip velocities and as the latter approaches the velocity of sound (750 miles an hour) the propeller becomes very inefficient.

It will thus be seen that the high altitude

plane will differ in many respects from the usual type of craft.

It has long been known that under normal conditions the temperature falls fairly regularly with increasing height. The rate of fall, or "lapse rate", as it is called, is usually in the neighbourhood of 1° F. for every 300 feet. On this basis it may be anticipated that at 37,000 feet, which is a little above the height that the Everest machine reached, the temperature will be no less than 100° F. lower than that obtaining at sea level. Such an intense cold introduces a host of new troubles. Taking the plane alone, we find a change produced in the operation of the controls. These are worked by steel rods or wires through various linkages. Unequal contraction of these latter has been found to cause failure in their operation. In the latest machine this has been obviated by careful attention to design.

How will high altitudes affect the engine? As with the plane, the fall of temperature and pressure will produce marked changes in its operation. The petrol engine receives its fuel in the form of a charge of air impregnated with a certain proportion of petrol vapour. This charge is driven into the cylinder by the pressure of the external air as the piston rises. Consequently a low air pressure will mean that the

cylinders will obtain only a reduced charge and the higher the craft the less will be the power developed by the engine.

At 43,976 feet, the height attained by Flight-Lieut. Uwins on his record-breaking flight, the air pressure is but one-seventh of that at sea level. Clearly an ordinary engine under such conditions would be practically starved.

A way out of the difficulty is found by adapting to aero-engines a device that is often employed to increase the output of racing-car engines. This device, known as a supercharger, is a type of pump or blower which is used to increase the pressure of the incoming charge. There are two main classes of superchargers. In the first the pump is so arranged as to increase the pressure of the air before it reaches the carburettor, in the second the pump lies between the carburettor and the inlet manifold, and thus increases the pressure of the incoming charge directly instead of boosting the pure air before carburation takes place. The pump, whatever its form, requires energy to drive it. This energy must, of course, be taken from the engine itself, a loss, nevertheless, that is far more than counterbalanced by the remarkable increase of power now generated by the engine.

Much more might be said of the difficulties with which aero-engine designers must cope

if they are to produce an altitude record-breaker. We might consider the effect of excessive cold on the fuel and the carburettor and the resulting explosive mixture. Or again we might note the need for controlling the cooling of the engine itself or the necessity for keeping the lubricating oil at a suitable temperature. Space will not permit the examination of these problems.

" Your Instruments are always Right "

We will turn to yet another side of the subject. At very great heights, owing either to clouds or other forms of poor visibility, the surface of the earth may be unseen for long periods and the pilot is compelled to resort to " blind flying " by the aid of the various instruments with which the aeroplane is fitted. Now the motto of the " blind flier " is " your instruments are always right ". Implicit reliance must be placed in them. But are the instruments always correct at high altitudes? Unfortunately that insidious fall of pressure is at work again, and, as will be seen, interferes with the accuracy of the air-speed indicator.

This instrument, as the name implies, records the speed of the plane through the air and not its speed relative to the ground. Essentially it depends for its operation on the pressure of air induced in it by its forward motion. But if

there is less air to affect it the readings obtained will be always on the low side. It is rather surprising to find the extent of the induced error. As low as 5000 feet the indicator shows 100 m.p.h. when the real air-speed is 108 m.p.h. At 15,000 feet although the air speed may be 113 m.p.h. the instrument records only 90 m.p.h. One more example will suffice. A plane passing just above the summit of Everest (30,000 feet) at a speed of 124 m.p.h. would register on the indicator but 76 m.p.h. The pilot must then consult a table of corrections if he is to be aware of his true air speed.

Again, the compass card will not function consistently at great altitudes, for the earth's magnetic field becomes reduced in intensity.

Then intense cold will cause lubricating oil to become very viscous if not actually solid. Instruments that require lubrication will thus be rendered insensitive or they will cease to register altogether.

The cameras were among the most important instruments carried by the air expedition to Mount Everest. It may not be generally known that the celluloid that forms the basis of the photographic film, changes its nature at about —20° F. and becomes so brittle that it cannot be bent without its breaking. As the cabin of the P.V. 3, in spite of its special construction,

was as cold as -40° F. the cameras were warmed electrically.

Practically every instrument, then, is affected to such a degree that corrective tables have to be used by the pilot to enable him to obtain a true estimate of his position.

When the numerous and immensely difficult problems that confront the high altitude aeroplane designer and engineer are thus considered, it is easy to understand and share the admiration and enthusiasm of Uwins's tribute to the makers of the Vespa, who have also to their credit the production of the Supermarine S6B, the seaplane that under the skilled and courageous control of Flight-Lieutenant G. H. Stainforth, won for England the World's Speed Record of 407·7 miles an hour, since lowered by Italy.

As for the part played by Uwins in this splendid adventure, it is but necessary to add that he was one of the first to receive the British Medal, a new award founded in 1933 by the Royal Aeronautical Society to honour aeronautic achievement of outstanding merit.

It is generally agreed that the future of aerial travel lies within the Stratosphere. Such a feat, therefore, as Cyril Uwins's is far more than the breaking of a record—it is an advance upon means of travel that will lead the next generation to new conceptions of time and distance.

CHAPTER XV

How The Temple of Knowledge has Grown

More than 150 years have passed since that memorable day, 15th October, 1783, when Pilâtre de Rozier and the Marquis d'Arlandes astounded the people of Paris by leaving the surface of the earth for a space of 25 minutes, thereby becoming the first travellers in the realms of the air.

These long years have been filled with the chronicles of many stirring ascents, a selection of which has been related in the earlier chapters of this book. Now, what has man to show for a century and a half of research? Has he found out all that is to be known of the mysteries of the aerial ocean which surrounds his planet? If not, does he still approach the problem from the same angle and by the same means as of old?

When we seek an answer to these questions we are struck by the great store of knowledge that has been laboriously gained but still more

do we realize that after all, the unknown is immensely greater than the known. Let no one imagine that further work on this fascinating subject is futile. We have but touched the mere fringe of a series of problems whose nature is intriguing and whose possibilities are boundless. All the keenest weapons of research which may yet be forged will be urgently needed to prosecute further studies into the nature of the structure of the air.

Certainly the angle of attack has altered almost beyond recognition since the days of the Montgolfiers and their compatriots. No longer is it sufficient for an observer with a few simple instruments to ascend in a balloon. Life has become more complex. Theoretical physics has developed far beyond the vision of the early experimenters. Thanks to new instruments of almost miraculous precision and sensitivity an entirely new technique of research has been evolved.

The remarkable discoveries of modern science have been successfully applied to old problems. Optics, radio, photography, acoustics, chemistry, spectroscopy and physics have been pressed into service.

As for the man, the observer, no single person can combine in himself the necessary specialized knowledge for the elucidation of the intricate

problems now involved. It is the day of the specialist, and the co-operation of many is necessary if we are to profit to the full by the many observations that are continually being made in all parts of the world.

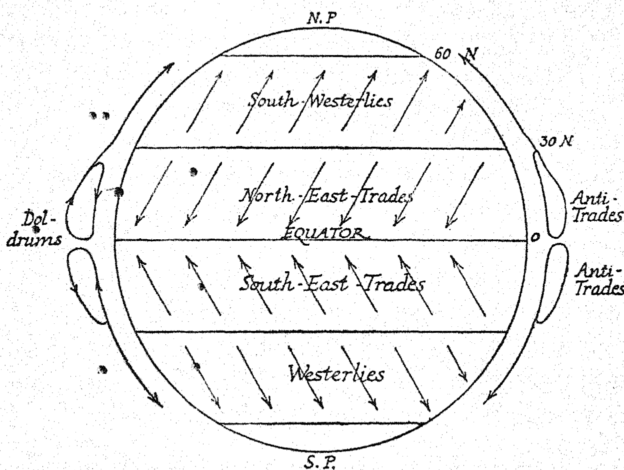
And what has been found by virtue of this collaboration?

The Circulation of the Air

It may be recalled that one of the aims of Glaisher was to map the currents of the upper air with a view to determining whether there was any definite and lasting system of air circulation.

In addition to the so-called "planetary circulation" of the lower air, it has been discovered that in the neighbourhood of the equator there is a steady easterly wind up to a height of 30,000 feet. The diagram (page 173) shows that the trade-wind area extends roughly from 30° N. Lat. to 30° S. Lat. Now at high levels it is known that there is often a complete reversal of the direction of the wind in these regions and another current known as the anti-trade blows strongly. The height at which these reversals occur varies with the season of the year, being in some cases as low as 3000 feet, while at other times the change will not be found below 19,000 feet.

It may be wondered to what extent the surface features of the earth make themselves felt in the air. As high as 6000 feet it is sometimes possible to feel the up or down currents caused by the earth's contours.



Planetary Winds

Large scale movements of the lower air such as the Monsoons appear not to extend above 19,000 feet.

One very interesting conclusion that has been reached is that at 30,000 feet or so in temperate and polar latitudes there is a continuous whirlpool-like westerly wind.

In view of the rapid progress that is being

made in aviation it is interesting to speculate on the possible uses of such winds in the future development of world air transport. Might not a valuable saving of time and fuel be achieved by the selection of a favourable altitude for flight?

That these world-wide movements of the air are no mere scientific speculation is amply proved by the strange results that followed the terrible volcanic eruption of Krakatoa in the East Indies about fifty years ago, when half the island was blown to pieces. The dust particles so produced were carried to great heights and were ultimately swept right round the world several times. By their selective absorption of the sun's rays these minute particles were responsible for a long series of sunsets of extraordinary beauty on the British Isles.

Atmospheric Electricity

In the earliest days of man's life upon the earth he must have been awestruck by vivid flashes of lightning and terrified by the crash and reverberation of the thunder as it echoed from cloud to cloud and from hill to hill.

It was not however until the experience of Benjamin Franklin, who drew a number of sparks from the string that held his kite, that it was recognized that even the air of a clear

sky was electrically charged. What was the magnitude of these electric forces? Did they vary from time to time, with altitude, or with latitude?

Research has yielded much surprising and interesting information concerning atmospheric electricity.

A word or two in explanation of some electrical terms will simplify the description of the phenomena that have been observed. The term potential is somewhat analogous to hydraulic "head". The energy of a waterfall depends on its volume and the distance through which the water has fallen. The latter is the difference in level between the top and the bottom of the fall and it is this distance which is known as "head".

In a somewhat similar way the difference in energy levels between two electrically charged bodies is described as their *potential difference*. Now, just as head of water is measured in *feet* so potential difference is measured in *volts*, and further as the rate of flow of the water is recorded in gallons per minute, so the electrical current is measured in amperes (coulombs per second).

By taking the average of a large number of observations it is learnt that as one rises from the surface of the earth the potential difference

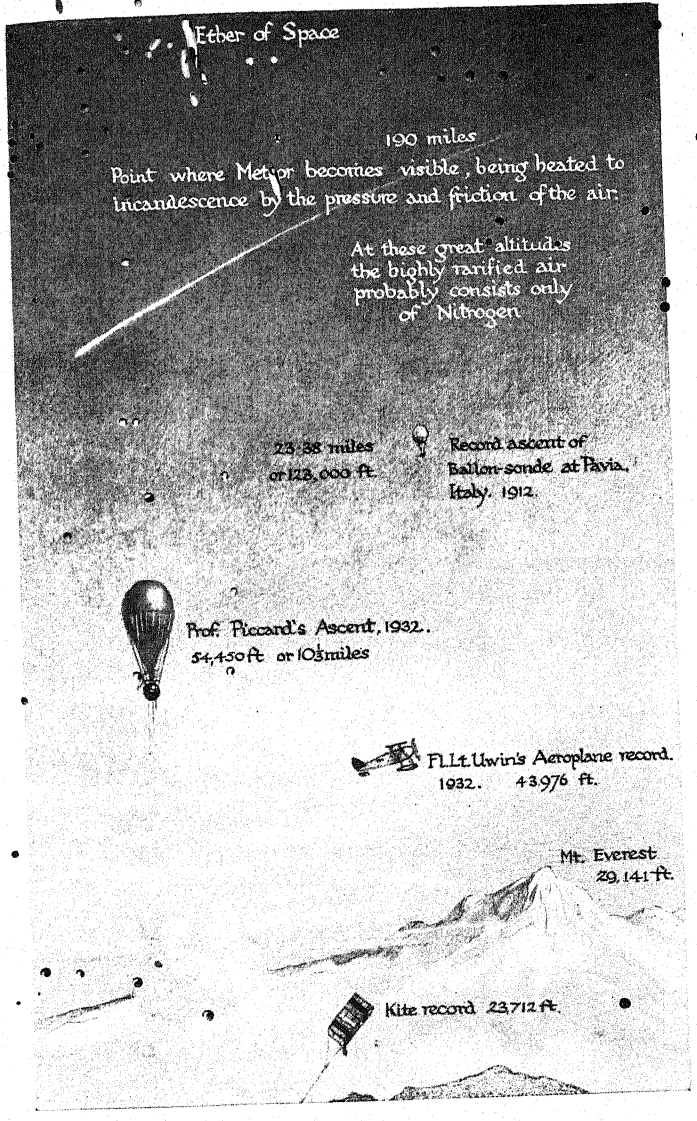
increases at the rate of 150 volts per metre. This rate of increase or decrease is called the potential gradient. This figure of 150 volts per metre is surprising, as will readily be seen if, for an example, the height of Snowdon is taken. This mountain is about 1000 metres and thus there may be a possible potential difference of no less than 150,000 volts between the air at its summit and that at sea level. Considering this enormous voltage it may be wondered why there is not a correspondingly great current flowing down to earth. When it is noted, however, that although a current is directly proportional to voltage yet it is inversely proportional to resistance, there then is the explanation. The resistance of the air is so high that very little current passes to earth.

Although the figure given is an average value, there are times when it is vastly exceeded. In conditions of fog it has been known to reach the magnitude of 2000 volts per metre at Kew.

In thunderstorms the potential gradient rises to as much as 10,000 volts per metre.

How the Clouds become Charged

Man has attempted to provide a satisfactory explanation of the origin of these differences of electrical pressure. It is now generally agreed



RECORD ASCENTS SHOWN DIAGRAMMATICALLY

Up to the present the balloon has won the race to the upper air, Professor Piccard on his second attempt (1932) having reached a record height of 54,450 feet. The world's altitude record for aeroplanes is held by Flight-Lieut. Uwins (1932).

that one of the most important causes is the break up of raindrops.

By reason of collisions with others of its kind, a falling raindrop gradually increases in size, until a stage is reached when it becomes unstable, and breaks up into several smaller ones, each of which as a result of the process becomes charged with electricity.

Naturally the presence of powerful up-currents will accelerate the operation and indeed thunderstorms are usually found to be associated with violent up-currents.

At very great heights the electrical resistance of the air falls considerably and at $5\frac{1}{4}$ miles it has been found to be 26 times less than at the surface.

Why should this be so?

Electrons and Protons

Modern electrical theory assumes all electric currents are the collective result of a vast number of electrons or atoms of negative electricity.

All matter is held to consist of complex atoms composed of electrons and protons (atoms of positive electricity) in such proportions as to cause the total resultant charge to be zero.

If owing to any cause, an atom loses one or

more of its free electrons it becomes positively charged, if on the other hand the reverse occurs the charge is negative. Such unbalanced systems are called ions.

Now it appears that both sunlight and cosmic rays are able to ionise the molecules of the air. The higher the molecules are the more intense the radiation which they encounter and so it follows that the air at great altitudes is extensively ionised at any rate during daylight hours. The movement of these masses of ions constitutes an electric current and any potential differences that may exist tend to be neutralized by this increase in conductivity..

Robot research in the Upper Air

The story of the ascent of Piccard has shown how far man has been able to float into the Stratosphere. It appears that his ascent is very near the limit of the ceiling for manned balloons.

For many years now it has been customary to explore the great heights by other means. It was in 1894 that the first ballon-sonde, or sounding balloon ascent was made. The balloon, which was very large compared with the modern ballons-sondes, had a capacity of 8825 cubic feet. Constructed of silk, the *Cirrus* made several ascents, the highest of all being

made in September, 1894. Automatic instruments were used to bring down the results of the investigations.

The success of these experiments, which were carried out in Berlin, aroused great interest in Europe, and we find that eventually France, Germany, Austria, Belgium, Italy and Russia co-operated with England in making ballon-sonde ascents on the same dates.

Later in England a series of ascents were made at Manchester by ballons liberated hourly for a period of twenty-four hours.

The Meteorograph

Even in a manned balloon a mercurial barometer would be a cumbersome type of altimeter, so the aneroid instrument is commonly used. This lends itself to automatic recording. For this purpose a small drum, round which a strip of paper can be fastened, is rotated by clockwork at a regular speed. A pen operated by the barometer needle traces a line on the paper as it is driven round. If the air pressure remains unchanged the line will be straight, but any deflection from the normal denotes a change of pressure. The paper is ruled with lines both vertically and horizontally. The horizontal lines mark the passage of time in hours and minutes whilst the vertical ones indicate the

air pressure, or, if so calibrated, the altitude in feet.

A somewhat similar kind of instrument is in use for recording temperatures automatically, by making use of the expansion and contraction of metals with varying temperatures.

For the determination of the relative humidity of the air, Regnault's Hygrometer is unsuitable for use in a ballon-sonde. Now human hair, when thoroughly cleansed from all fat by boiling in a strong alkali, has the property of changing its length with the relative humidity of the air. In the recording hygrometer, a bundle of hair is supported, and a pen, attached to the middle of it, is arranged to register the relative humidity upon a calibrated chart wound on a drum revolved by clockwork.

Instruments of this kind, although extremely delicate and needing careful attention, can be made to yield valuable information when used in conjunction with the ballon-sonde.

The modern ballon-sonde is quite a small affair with a diameter of about four feet. It is unable to lift much weight and great ingenuity has been expended in the production of really light recording instruments.

An extraordinarily efficient instrument, known as the Dines Meteorograph, which weighs only two and a half ounces, was designed and made

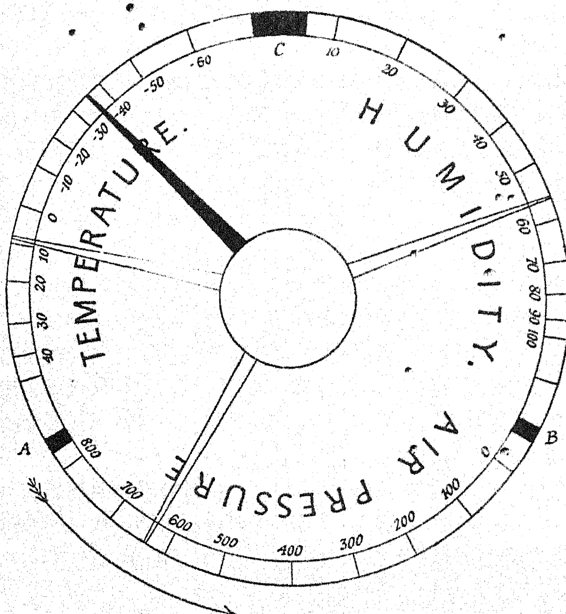
by W. H. Dines. In this the recording strip of paper is replaced by a tiny piece of highly polished metal not much larger than a postage stamp. The mechanism operates minute needles which scratch the record on the metal on such a small scale that it has to be read with a magnifying glass. Enclosed in a wire framework or "spider" it will safely bring to earth the secrets of the upper air.

The Radio-Meteorograph

A very clever device has recently been developed from the original Dines instrument by a Russian, Prof. Moltchanoff. The new meteorograph is of a distinct robot-like character, since it not only measures pressure, temperature, and humidity, but telegraphs a graphical record by radio to the observers on earth while the actual flight is in progress. So interesting is the mechanism that a short description is not out of place.

Picture a round disc like a clock face, around the edge of which, instead of the hours and minutes, are engraved scales of temperature, pressure, and humidity; there are three hands or pointers, one for each scale. These three hands are operated by similar methods to those in use in the ordinary type of recording thermometers, barometers and hygrometers.

Separating the three scales are three contact pieces, A, B, and C, of which C is considerably longer than its neighbours.



Radio-Meteorograph

There is yet a fourth hand, the motion of which is not confined to any one sector, but is driven continually by clockwork at a constant speed round the full circle.

This last hand is really a contact arm which revolves, like the minute hand of a clock, just

above the other three. During its passage it makes a short contact as it passes over each hand and also with the three contact strips A, B, and C.

For simplicity let us consider only what happens in the temperature sector. Suppose that the fourth hand is making contact with C. As long as it is doing so a continuous signal is transmitted by a small self-contained radio set in the instrument. When it leaves the end of C the circuit is broken and the signal ceases. The arm moves on until the temperature hand is reached when contact is made again and a short signal transmitted.

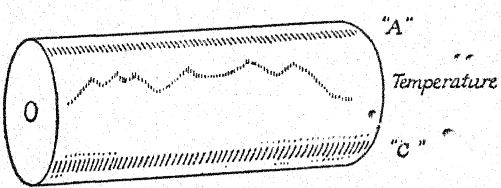
Now it will be seen that the higher the temperature the longer will be the interval between these two signals, indeed the size of the interval is a measure of the temperature.

Simultaneously with this operation, a receiving apparatus akin to the Fultograph Picture Receiver is at work. The instrument consists in part of a drum revolving at exactly the same speed as the contact arm on the transmitting disc. A sheet of paper is wound round the outside of the drum. A pen, which is operated whenever signals arrive, presses on the paper and makes a mark for as long as the signal continues.

A similar series of operations is performed as

the contact arm travels over each of the other sectors. One complete cycle of operations therefore appears on the record as a series of six lines.

First comes a fairly long one produced by strip C. The second will record the temperature, while the third gives the reference line of contact



Fultograph-Radic-Meteorograph Record

A. The next mark is the air pressure in millibars. Then follows the line B. Lastly is recorded the percentage of humidity.

When one revolution has been completed the drum moves along a little so that the next set of lines are placed beside the first. The continued sequence of these lines produces three lines of reference together with the " traces " of the changing temperature, pressure, and humidity.

By means of this ingenious mechanism does the radio-meteorograph tell the story of its ascent and descent.

N.B.—" Millibar " is one thousandth of a

"Bar" which is the modern unit of air pressure. 1000 mb. = 750·1 mm. = 29·531 inches.

The Composition of the Upper Air

At the lower levels the composition of the air, except for slight changes in the quantity of water-vapour, remains practically constant all over the world.

Speculation as to the probable constituents at great heights has been rife during the last 50 years. Since no ballon-sonde ascent has yet exceeded an altitude of 24 miles indirect methods of research must be employed to add to our knowledge of these regions.

At first sight it would appear difficult to find any methods of discovering the nature and proportions of the gases present in the high levels of the atmosphere.

The ingenuity of man, however, seems boundless, and in these days it is generally found that one branch of science can be called upon to solve the problems of another. Thus we find that meteorology is beholden to optics and the science of radiation for the further elucidation of these difficult questions.

That wonderful instrument, the spectroscope, by whose indications man is able to determine the physical and chemical nature of the vastly remote stars is now applied to the

analysis of the upper air. By examining the difference in the spectrum of sunlight, when the sun is high above and low down towards the horizon, estimates have been made as to the quantity and location of ozone in the upper air. It has been established that this gas occurs in a layer between 19 and 25 miles above the surface of the earth.

Ozone absorbs a proportion of the sun's ultra-violet radiation. In the process the temperature rises. It is for this reason that it is thought that at extreme altitudes the highly rarefied air may be very hot—as much as 1000° F.

The Troposphere and Stratosphere

The many balloon ascents up to the year 1899 all went to prove that, generally speaking, the higher one went the colder it became. At this time, however, Teisserenc de Bort discovered that at a height of about seven miles over Europe the temperature ceased to fall. The lower levels in which the old law held was named the Troposphere while the newly discovered region was known for a time as the "isothermal" or equal temperature layer. This latter name is not appropriate, for although the temperature does not vary with height, yet it does change with horizontal movement.

Assmann and de Bort suggested that the region above the Troposphere should be called the Stratosphere and this is now firmly established. The boundary layer between the two is called the Tropopause.

The height of the Tropopause varies with latitude, being highest at the equator and lowest in the polar regions. Its average height at the equator is about twelve miles and in the neighbourhood of the poles it is probably not more than five miles.

The height of the tropopause varies from day to day, and in general is found to be lower when the air pressure at sea level is low, while a rising barometer usually betokens a rise of the tropopause also.

In consequence of the great altitude at which it lies in the equatorial zone, it is to be expected that the temperature there will be very low, and indeed, the lowest natural temperature ever registered was recorded at a height of $10\frac{1}{4}$ miles above Batavia, Java. The figure was $-131{\cdot}6°$ F.

It may well be wondered why the atmosphere should be divided into these two shells and why the dividing line should take up the position that it does.

The whole question of the physical processes of the air that affect this problem are very complex, but broadly speaking, it may be said that

one of the most important factors at work is the quantity of water vapour present in the air.

This amount of water vapour largely controls the power of the air to absorb or radiate heat and thereby governs the production of convection currents.

Convection currents may be studied if a beaker of water with small particles of matter in suspension be heated from beneath. It will then be seen that as the water is warmed, and consequently expands and becomes lighter, it will rise and cooler water from elsewhere will sink to take its place. The upward curling smoke from a cigarette illustrates convection currents in the air.

Large scale up and down movements of this type in the atmosphere naturally transfer great quantities of heat to different levels, in consequence causing changes in the lapse rate.

Now, convection currents are characteristic of the troposphere but seem to be absent in the stratosphere; furthermore, water vapour is also absent from that region.

It would thus appear that the separation of the two shells is largely the result of the distribution of water vapour. In confirmation of this it should be noted that that part of the world where the troposphere extends highest is the equatorial region—a region which, owing

to its great heat and extensive ocean surfaces, is certain to be productive of an amount of water vapour well above the average.

The Aurora as an Aid to Research in the Upper Air

Explorers in the barren wastes of the far north have brought back delightful accounts of the beauty of the auroral displays that are frequently visible in high latitudes.

Nansen on the Aurora

"The Northern Lights were exceptionally beautiful," writes Nansen. "When I came out at six o'clock there was a bright pale yellow bow in the southern sky. It remained for a long time unchanged, and then began to grow much brighter at the upper margin of the bow behind the mountain crests in the east. It smouldered for some time, then all at once light darted out westward along the bow; streamers shot up all of it; towards the zenith it was aflame. It flickered and blazed, it whirled round like a whirlwind (moving with the sun), rays darted backward and forward, now red and reddish violet, now yellow, green, and dazzling white.

"Higher and higher it rose, now it came on the north side of the zenith too; for a moment

there was a splendid corona, and then it all became one whirling mass of fire up there; it was like a whirlpool of fire in red, yellow, and green, and the eye was dazzled with looking at it. It then drew across to the northern sky where it remained a long time, but not in such brilliancy. The arc from which it had sprung in the south was still visible, but soon disappeared. The movement of the rays was chiefly from the west to east but sometimes the reverse. It afterwards flared up brightly several times in the northern sky; I counted as many as six parallel bands at one time, but they did not attain to the brightness of the former ones."

Aurora is the Latin word for dawn and the name Aurora Borealis as applied to these displays is of no recent origin, since it is said to be due to Gassendi who first made use of it in 1621. In more recent times travellers in the Antarctic have seen similar phenomena and have called them the Aurora Australis. The adjectives are now no longer used and the term aurora embraces the spectacle about the poles in either hemisphere.

What are these strange yet beautiful lights that "dance on the houseless snow"?

What is it that glows at times with pale spectral light? Is there any heat associated with

the light? What is it that causes the glow to appear at all?

When writing of the electrical condition of the air it was observed that at great heights the conductivity was much greater than at the lower levels. Indeed, at an altitude of 95 miles there is a mighty current of 29,000,000 amperes steadily flowing round the world.

Now, by methods that will be explained later, the height of the auroral displays have been measured. It is found that they vary considerably in height. Occasionally the phenomena are seen at no less than 125 miles, but more often they lie between 55 and 80 miles.

All these zones are well within the region of good conductivity and so the aurora are held to be discharges of electricity in extremely rarefied gases.

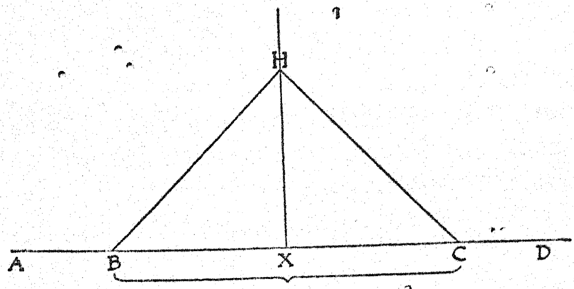
What are these gases?

Once more the spectroscope has been called in to give a decision and, according to McLennan of Toronto, the most prominent lines in the spectrum of the aurora are those due to Oxygen, which is thus proved to be present in the atmosphere as high up as 125 miles.

Finding the Height of the Aurora

If it is wished to find the height of an inaccessible object it is possible to do so by noting

its angular altitude from the ends of a measured base line.



Suppose it is required to find the height of H above the ground level ABCD. The base line BC must be accurately measured. Then with some angle-measuring instrument such as a theodolite or a sextant the values of the two angles must be carefully determined. These figures being known it would be a simple matter to construct a scale drawing of the various positions from which the height of HX could readily be found.

In actual practice it is unnecessary to make a scale drawing since a reference to a book of trigonometrical tables would soon solve the problem.

A new method especially developed for the purpose of measuring the height of the aurora has been introduced by Prof. Stormer. This

is also a trigonometrical method, but the system of determining the angles at the ends of the base line is novel. Cameras are set up at each end of the line and photographs of the aurora are taken simultaneously. Now the same fixed stars will appear as a background in each photograph. But as a result of the different points of view the aurora will occupy a slightly different position with regard to the fixed stars which may thus be used as reference points. From this data it is possible to calculate the height at which the display is occurring.

One fact that has been discovered is that the amount of ozone present in the air in high latitudes is generally greater after the long winter night. It seems to be fairly well established that the ozone content is also increased as a consequence of magnetic storms. Is it not likely that the aurora, as other types of electrical discharge, may be responsible for the production of ozone?

It is remarkable, nevertheless, that the ozone layer at 40 or 50 Km. (25–32 miles) is far below the level at which the displays take place.

The Quest Goes On!

It must be admitted that we have at least something substantial to show for the untiring labours of 150 years—certainly the foundations

of the Temple of Truth have been well and truly laid. But after all it is still only the foundations and it is improbable that the structure will ever be complete. There will always be room for the erection of yet another storey or a pinnacle here and there.

Does the present condition of the building suggest that any further work upon it is advisable?

Will the views obtained from the rising structure repay mankind for the labour spent thereon?

Surely the answer to each question is in the affirmative.

The whole science of meteorology is bound up in the study of the air and a more exact meteorology must be of inestimable value to the future of the world.

The debt that man owes to meteorology seems ever likely to increase.

An ample and cheap food supply is dependent in a high degree on weather conditions. A disaster to the Canadian wheat crop may well be due to the effects of frost which might have been obviated by later sowing had the farmer had sufficiently early warning of its impending approach.

In the early chapters of Jewish history we read of the advantage that Joseph was able to reap

by his foreknowledge of the impending seven years of famine.

Of what immense value would the certain knowledge of the behaviour of the monsoons for a series of years be to the government of India.

Again, the sailor often runs into danger, and even disaster, through the havoc and stress of storm. To such, long range forecasting would be invaluable.

In the navigation of the air itself the pilot cannot know too much of the air and its ways. Upon its physical condition his craft depends for its support and like the mariner he would welcome the assistance of accurate long range forecasts for wide areas.

Prevision of the strength and direction of currents at various heights would enable him to save both time and fuel in many cases.

Recent investigation seems to indicate that the weather at the earth's surface has its origin at levels not less than six or seven miles up.

The quest must go on.

CHAPTER XVI

Towards the Stars

The Latest Enterprise

"It will take about three terrestrial days for the journey to the moon and back, and at least an additional three days for hasty exploration, making a total of six days in all." (Extract from address by Nathan Schachner* to the American Interplanetary Society, 1931.)

Of every one of man's great enterprises there is a story to be told finer than the finest piece of fiction. It is a story of man at his very best.

There is always the bright vision, the audacious purpose; faith, hope, despair, failure and success, romance and tragedy.

Too often we have been unaware of all this. We have missed the early thrilling chapters, and read only the last. The great adventure too often has been achieved almost before we knew it had begun.

And now there is an enterprise afoot seemingly impossible—as impossible, in fact, as all

* President of the Amer. Interplanetary Society.

those others that, to the confounding of the sceptic, have at last been brought to a happy ending in the gift to mankind of some inestimable advantage—some splendid revelation.

Will this great enterprise succeed?

We can but tell the story as far as it has developed, and ask the reader to supply the final chapters.

As we have written, by indomitable patience and courage man has now penetrated as far into the air as the crafts of his ingenious fashioning will carry him.

When the English pilot, Flight-Lieut. Cyril Uwins, recently took the World's Altitude Record from Lieutenant Soucek of the American Navy, with a height of just under 44,000 feet, he was near the limit of an aeroplane's capacity.

Beyond that point the air is so thin that it is unable to give the necessary lift to the plane, and the propeller would simply whizz round with nothing or next to nothing to bite upon.

As for the balloon, with an even greater range than the 'plane, Glaisher and Coxwell, in 1862, penetrated the Stratosphere in the open car of their craft when Glaisher nearly lost his life, and in 1932, Professor Piccard and his assistant, Cosyns, were carried in their small sealed cabin farther still into that cold, windless, well-nigh airless region and both suffered severely.

Piccard said that they could have risen higher, but his 54,450 feet record is undoubtedly very nearly the limit. At that height about nine-tenths of the air lies beneath the explorer, that is, of the total weight of the air pressing down upon the earth, nine-tenths of it lies below 54,000 feet. There is only one-tenth, becoming more and more rarefied up to a height of roughly 240 miles, where the airless ether of limitless space may be considered to begin.

Piccard then has risen to the surface, as it were, of the supporting ocean of air.

Not quite, though. The ballon-sonde, or unmanned sounding balloon, fitted with scientific instruments, has travelled to the height of 123,000 feet, where the air is so thin that it can only just support the tiny globe.

Here, it would seem, is set the outpost of direct investigation of space, and that here man would recognize and accept his limitations.

But when was that ever so? The history of all development, all progress in all its myriad ramifications, clearly proclaims that there is no end to the daring and the ingenuity of man.

He will never rest content. From the vantage point of achievement there will always be the distant prospect of the unachieved. He will be led on from peak to peak for ever across the endless ranges of knowledge.

So with the aerial explorers who have already revealed so much to us. The long line is unbroken, and to-day, preparations are being made to blaze the trail farther into the unknown regions of space. And *blaze*, as will be seen, is certainly an apt word, here.

A craft has to be constructed that is not dependent in any way on the air for its lift, a craft that will travel at a great speed through the enveloping air, at a greater speed on through the intensely cold region of the Stratosphere on whose fringe Piccard has voyaged, on at a still greater speed through the remaining stretch of thin, and ever-thinning air, out at an incredible speed into mysterious space and away to the moon.

Putting Dreams to Action

The idea is not new. Most ideas have come trickling down through the ages, broadening gradually into the flood that at last has swept man to success. This one is at least as old as the Ancient Greeks, whose philosophers turned their curious thoughts to the stars, and it has been brought down to us by a host of imaginative writers.

There was the scientifically-minded Bishop Godwin, who, feeling sure that it was to the moon that birds migrated, suggested harnessing

geese so that they could carry a man to the moon and bring him back in the Spring!

Jules Verne, in his famous story, used a massive gun, 900 feet long, to project his vehicle into the air, apparently ignoring the fact that an occupant would be squashed as flat as paper by the terrific shock of the initial explosion, whilst the projectile itself would, in its passage through the air at so great speed, become white hot and burn away before it had reached airless space.

Then Edgar Allan Poe, thinking that the atmosphere stretched away to infinity, in 1835 wrote his romance, using a balloon to attain his hero's objective.

H. G. Wells very cleverly imagined an anti-gravitation material, named Cavorite, which would nullify the attractive force of the earth. The craft, covered with this material, would be sent away from the earth, until it came within the range of the attractive force of the moon. At that point, the covering of Cavorite on the moon-side of the vessel would be rolled up so that the moon's force of gravity could pull it to its destination.

A very clever idea, but unfortunately there is as yet no Cavorite.

Two of those imaginative writers, however, were strangely prophetic, for in 1640, Cyrano

de Bergerac, in his *Voyages to the Moon and Sun*, sent his explorers up in a rocket-propelled vessel, and Jules Verne, in 1866, to prevent his imaginary craft crashing, after it had passed beyond the earth's attractive force into the moon's, used rockets at the nose to slow it down.

For hundreds of years then, the idea had been about in the world, but by the end of the nineteenth century it was scarcely considered a subject for serious discussion.

Then it caught, independently, the imagination of several brilliant men of science, in different countries.

In France, there was Robert Esnault-Pelterie, a man of science, and an engineer second to none in the brilliance of his inventive intellect. He had thrown himself wholeheartedly into the infant sciences of aviation and radio and rendered invaluable service. He was the designer, for instance, of the R.E.P. monoplane. Now his mind was attracted by the mystery of the regions of airless space, and he gave himself up to the study of the possibilities of one day reaching them.

A deep and prolonged mathematical and technical research so completely confirmed his belief that the ether of space could be navigated that he had no hesitation in giving the

weight and authority of his name to the project.

He wrote papers, lectured to scientific societies, experimented, and spent considerable sums to advance the theme.

In Belgium, the idea was likewise working in the mind of Dr. Andrée Bing. Independently, he had concluded that, in spite of enormous difficulties, the higher regions could be reached, and his theories and experiments had, in 1906, culminated in his being granted a patent for a machine for exploring above the air.

Then the famous Austrian physicist, Dr. Hermann Oberth, devoted himself to the question and some five years of research brought him to the same view as Bing and Pelterie.

Support came from Germany, from no less a figure than Dr. W. Hohmann, who after a long period of study subscribed to the findings of those others. And there was Valier—Max Valier—and to a splendid cause there could not be found a more splendid adherent. Tragedy came to him, but not before he had written a stirring page.

Both Oberth and Pelterie aroused great interest in scientific circles by the publication of their mathematical and technical surveys of the subject, Pelterie's *L'Astronautique* being a survey of deep significance. Pelterie, too, with the good offices of his friend and co-worker

André Hirsch, established the Rep-Hirsch Fund, with a committee of some of the most eminent French men of science, to encourage research in Interplanetary Exploration by awarding an annual sum of 10,000 francs for the best paper submitted on the subject.

Education of the Russian mind was being gradually achieved by a group of scientists under the leadership of Professor Nikolas Rynan, so that throughout Europe there was a general leavening.

As for America, Dr. Goddard, by a long series of experiments, first at Princeton University and later at Clark University, had become so convinced of the possibilities of reaching extreme altitudes that he interested that august and eminently sane scientific body, the Smithsonian Institution, to the extent of their making him a substantial grant for further research.

A great step forward, too, was taken when, in 1930, the American Interplanetary Society was formed by a number of scientists and technicians. There came also the German Interplanetary Society, and now there is being formed the International Interplanetary Commission, a body of eminent scientists to organize and co-ordinate all the research of the various associations throughout the world.

Those enthusiastic workers, enthusiastic because relentless scientific analysis had supported bold imagination, were struggling finely against scepticism and indifference. They had to break through the prejudice of Common Sense, ever so ready to confuse the unachieved with the impossible.

A Strange New Craft

A craft, then, had to be devised that was absolutely independent of the air for its propulsion, and it is upon the rocket that all these scientists and engineers place their faith.

By rocket to heights far above the 123,000 feet of the ballon-sonde, out into the ether of space.

A host of immense difficulties crowd into the mind. There is the intense heat of friction through the air—heat that will bring the metal casing of the projectile to a state of incandescence, there is the heat and shock of the initial explosion which would instantly kill; there is the intense cold of the Stratosphere, the intense *heat* of the higher region, the intenser, paralysing cold of the ether. The biggest gun constructed can throw a shell but a comparatively few paltry miles, and it is 240,000 miles to the moon. How could a rocket be guided at such a colossal speed? How

will they land when they get there? Through those thousands and thousands of miles of airless space in a rocket. . . .

A mad, impossible scheme!

There are indeed a thousand and one hows—fascinating, thrilling hows. But let us not be too hasty with our scorn.

When the Montgolfier brothers were working at their first balloon that was to go up only a few hundred feet into the air, they were considered not only mad but wicked.

When the long, long dream of the aeroplane was near realization, the pioneers were looked upon as very amusing cranks and, be it well noted, not a few mathematicians, arguing correctly from false premises, actually proved that their project was impossible.

As for wireless——!

Yes, but this is so different, it is said, so much more difficult. Always it is the same. Always the unachieved is the impossible. O we of little faith!

There is this to be said, though. It is not altogether a matter of lack of faith. It is as much a matter of misconception. So many think it means being shot up by one tremendous explosion that will carry the projectile, in one hop, to the moon, which of course *is* a folly.

What is the principle, then?

Consider a gun. The explosion within the breech sends the bullet forward and the gun backwards, *with an exactly equal force*. The bullet, being small compared with the gun, flies away at a great speed; the gun gives the familiar kick.

If the gun and the bullet were of the same weight they would fly away in opposite directions *at the same speed*, because *action and reaction are equal and opposite*. That is the scientific principle of the rocket. An explosion within it causes a rushing forth of gas. If both ends of the rocket were open, there would be no movement. Close one end and there is an outward rush of gas at the other, but there is an equal force in the opposite direction which, unable to escape, drives the rocket up and away.

Let us repeat: It is the equal and opposite reaction of the explosion *within the rocket* that gives it its velocity.

It will readily be seen, therefore, that a rocket should be more efficient in a vacuum where there is no air-resistance, and Dr. Goddard has proved in the laboratory that this is so. The rocket, then, is the one means of propelling a vessel through the vacuum of space.

One mighty explosion to send the rocket

away through space is obviously ridiculous. But supposing you have two charges within it so that when the effect of the first has diminished, the second will renew the velocity. And instead of two why not a number of charges to be fired at definite intervals? Extend that idea and you come to the conception of a continuous burning of the fuel to produce the propelling force. This is the principle upon which the pioneers are working. The Principle of the Step-Rocket.

Indomitable Perseverance

The question of the explosive to be used, the fuel, that is, is of the utmost importance. The greater its explosive power and the less its weight, the greater its efficiency.

Years were spent experimenting with every kind of *dry* fuel, such as gun-powder, to test their reliability, the volume, the heat, the relative expansion of the gases produced; the effect upon them and their efficiency, of cold and heat.

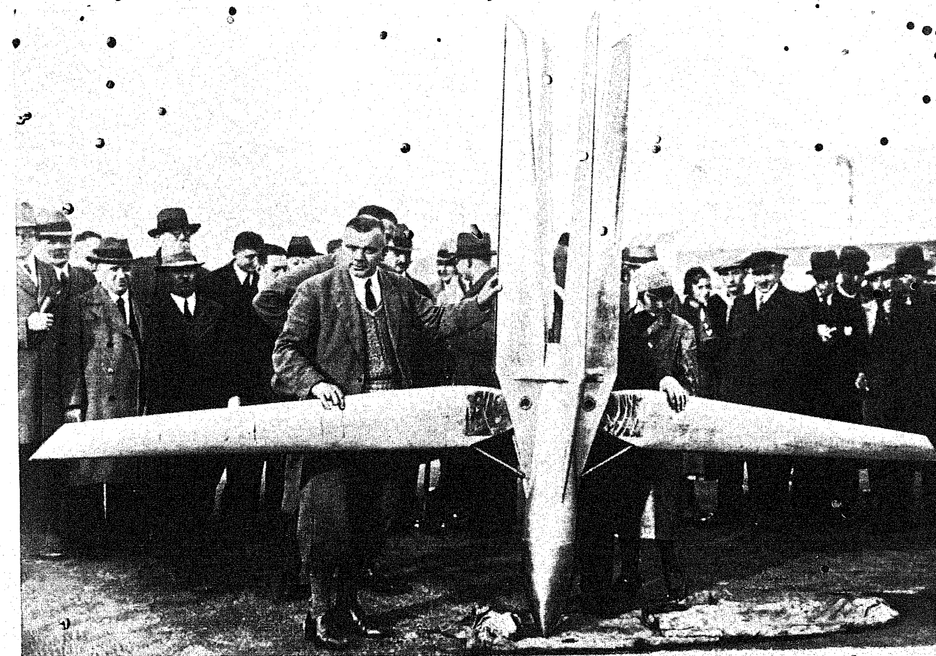
There was also to be tested by a thousand experiments, the method of feeding the fuel into the charge-chambers, the best design of the chamber, and the metal best fitted for its construction.

Cartridges were tried but were found to be unsatisfactory. They were too bulky and their

explosive energy insufficient. The design of the open end, the nozzle, was another vital point, for the more intense the outrush of gases, the more intense will be the equal and opposite reaction which gives the rocket its velocity. Therefore the nozzle was constructed and reconstructed not once nor twice but a hundred times, and the effect of each slightly different design on the issuing gases, carefully assessed and tabulated.

As for the material of the charge-chamber: What metal would best withstand the tremendous heat and strain of the fiercely burning gases? The metallurgist had many metals to offer, each possessing admirable qualities under different conditions of strain. All these metals had to be tested by subjecting them to the different influences and stresses of different explosives.

It is essential to keep down the weight of the projectile. Therefore the light metals were tested. They were satisfactory in the matter of weight, but they could not withstand the intense heat and strain. The heavier metals were experimented with, and then the alloys. Aluminium and beryllium, two of the better known light metals, can stand up to a heat of over 3000° F. and the explosive force of a very heavy charge. Steel weakened under the



Sport and General

HERR REINHOLD TILLING WITH HIS FLYING ROCKET AT THE CENTRAL AERODROME, TEMPELHOF, BERLIN

In a trial flight the rocket rose 2625 feet: the wings then automatically unfolded and brought the rocket safely back to earth

immense stress and the whole rocket blew up. Molybdenum, a heavy metal, can withstand a temperature of 4500° F. and has great strength. The experimenters, therefore, constructed the charge-chamber of an alloy of Aluminium and Molybdenum.

Cannot it be seen, the vast amount of work that is being done, and the unconquerable determination of the adventurers?

A First Rocket Adventure

The translation of theory into practice is always a fascinating, and frequently a most dangerous operation, as this story will show.

Dry fuels, after exhaustive testing, were abandoned as being not sufficiently effective, and liquid fuels had taken their place.

Liquid hydrogen and liquid oxygen, fed into the combustion chamber, gave an explosion of terrific power. How readily we all recall that noisy and therefore favourite experiment of our schooldays, when two parts of hydrogen and one part of oxygen, mixed in a stout soda-water bottle and fired, combined with a most satisfying explosion to form water.

Great volumes of those two gases, in their liquid form, could be conveniently carried and passed into the combustion chamber, where they could be continuously burnt.

The ground had been prepared, then. A dugout had been made, and a proving-stand (testing-stand) of two upright beams of wood, held by a supporting framework of planks. The uprights were fourteen feet high and designed to give the rocket a lead should it achieve actual flight. Sandbags and earthworks protected the whole from flames.

An excited and anxious little band of adventurers gathered in the field to carry out the tests. In the main, the rocket consisted of two long, cylindrical tanks of aluminium, one holding liquid oxygen and the other petrol. The motor (i.e. the combustion chamber) was mounted on a shackle at the forward end of the two tanks. An aluminium jacket about the chamber, filled with water, was designed to cool it. The rocket was attached to a twelve foot pole pivoted at one end to an upright post, and held at the other by a coil-spring, so that any movement of the rocket would be controlled by the spring.

The first test, that of subjecting the gas-cylinders to a pressure of 300 lbs. by means of compressed nitrogen, was simple. Not so the second, that of filling the cylinder with liquid oxygen. It had to be poured through an opening a half-inch in diameter, and the operation is very much like trying to pour cold water into a

red-hot, metal vessel. As soon as the oxygen touches metal it fizzes and spits, sending spray upon the face and arms of the experimenters, and causing spots of frostbite where it pitches. As the liquid goes down the funnel it meets an uprush of gas from the instantaneously vaporising liquid within. The funnel actually became plugged with frost, and altogether it took 45 minutes to empty three quarts, and then only one quart remained in the cylinder.

One who was there says: "With all hands in the dugouts, and a member timing the performance, I screwed in the safety-valve and ran for shelter, to await the building up of the pressure by boiling inside the tank.

"The safety-valve had been set to release at 300 lbs. pressure. We had been sure that the oxygen would build up to this pressure in a few seconds, and the last man scurried away once the safety-valve closed off the free escape of the gas. Actually after four and a half minutes the valve popped off. In the next experiment when the valve refused to budge Mr. Pierce went up with a long pole and knocked out the fuse-wire, releasing a beautiful cascade of liquid oxygen and gas. . . . We filled up both tanks again. Mr. Pierce attached his fuse-wires, then took his place at the controls in the dugout. My part was to finish pouring in the oxygen,

screw down the safety-valve, and retire to the dugout, to call out the firing orders. Miss Gregory was charged with timing the pressure period. Dr. Lemkin was ready with a box of matches and a petrol soaked torch, and Mr. Lasser * was waiting the signal to go forward with the torch and light the fuse between the tanks of the rocket.

"Dr. Lemkin lit the torch, which Mr. Lasser carried out to the rocket, igniting the fuse. For an instant there was a great flare, as the pure oxygen struck the burning fuse. In an instant the petrol was also pouring into the rocket. The fuse, the flare, and the uncertainty about the performance of our rocket-motor all disappeared at once, as, with a furious hissing roar, a bluish-white sword of flame shot from the nozzle of the combustion chamber, and the rocket lunged upward against the retaining spring. It is impossible adequately to describe that sight, or to convey the feeling it gave us. I suppose we were excited; but there was a certain majesty about the sound and sight which made it impossible for the moment to feel excitement as such. We forgot to remain behind the shelter of our earthworks. Moreover we forgot to count the seconds as they passed in that downward pouring cascade of fire. . . ."

* Ex-President of Amer. Interplanetary Society.

That gives some idea of the difficulties and the dangers of this latest enterprise.

Two Fearless Pioneers

In Germany, Max Valier and his equally adventurous friend, Opel, having built and experimented with many a rocket, determined to put the most efficient of them to the test.

Their method was spirited and original. Valier fixed rockets to the back of a motor-car, and on the Berlin Avus Speedway he obtained the remarkable result of a speed of 60 miles an hour, within 60 yards of his starting point. That was highly satisfactory. The rocket was a most powerful propelling force, and one that could be employed.

A little later, by an improved rocket design he raised his maximum speed to 130 miles an hour. That fired Opel to fresh efforts, and he built a car to which he attached even more powerful rockets. The car was wrecked at its second try-out. He built a second. That ran off the track, somersaulted down a bank and collapsed. He built a third and at a speed of nearly 50 miles an hour it blew up. He built a fourth, and to his chagrin, authority stepped in and denied him the right to risk his life in it.

Max Valier had better luck, for again he reached a speed of 131 miles an hour. At a

second attempt when the speedometer had registered 132 m.p.h. the car could not hold the track, and turning over, was smashed to pieces.

He was immensely elated at this. It was the car that had failed, not the rocket. The rocket had beaten the car; it had proved to be too strong for the craft it was driving.

What vehicle was there that would stand up to the speed that the rocket obviously could produce? A bright idea came to them. They built a sledge and rocketed it across the frozen surface of Lake Starnberg at a speed of 235 miles an hour.

Now for the next stage in development. Both Opel and Valier were certain that they could propel an aeroplane by means of rockets, and, a little later, Opel justified their faith. At Frankfort, rockets sent him up and away at a speed that reached 85 m.p.h. It was an experiment that ended in a crash and the smashing of his plane. But what of that? He had achieved his purpose. Everything must have a beginning. The embryo bears but little likeness to the grown thing. He was satisfied. In a few years, by rockets, a craft would be driving through space in the cloudless, airless regions above the Stratosphere, at thousands of miles an hour.

The End of Max Valier

Max Valier had by now aroused an enormous interest in the study of interplanetary exploration, among scientists and laymen alike. The very audacity of the project of speeding at thousands of miles an hour through the emptiness of space appealed to the imagination, and attracted many an enthusiastic worker and supporter.

Both Opel and Valier had abandoned dry for liquid fuel, and were favouring a mixture of liquid oxygen, water, and methylated spirits. Dr. Hoylandt had constructed a new design rocket-motor weighing only seven pounds and developing a horse-power at least five times as great as the most efficient aeroplane or car-engine of the same weight.

The two friends, after a series of exciting and most satisfying tests, were impatient to use the immense power of their new Hoylandt. A car was built to a design calculated to hold the track at a great speed. The rocket was fixed at the back. The great day had arrived. Valier was at the rear of the car making his final supervision, and checking the pressure-gauge of the new rocket. In a minute or so, in all likelihood, the car would be setting up new speed figures and stirring the minds of not a few

enthusiasts to an even greater enthusiasm.

And then it happened. Without any sort of warning there was a terrific explosion; a steel-blue flame, fifteen feet long, shot forth from the rocket-tank, the car bounded forward and collapsed, and Valier, blown high into the air, fell in a crumpled heap that did not stir.

Success

Death had stopped this splendid adventurer far from his goal, but the others, joined by more, led on. Esnault-Pelterie, at Paris, boldly proclaimed to a body of eminent scientists that a journey to the moon would be made within fifteen years. Dr. Goddard, in America, was continuing his experiments with ever increasing zeal and faith. He had built a rocket, equipped it with scientific instruments for registering meteorological conditions, and, with amazing ingenuity, fitted at its nose a parachute which, at the climax of its flight would automatically open and bring the rocket safely to earth, and so gently that the instruments would not be disturbed.

This rocket was nine feet long by two feet four inches in diameter. Outside Worcester was erected a steel tower, forty feet high and grooved to guide the rocket.

Goddard wanted to test a dozen things—the

durability of the combustion chamber, the efficiency of the liquid fuel, the balance of the rocket packed as it was with instruments and parachute, the efficiency of the nozzle design, of the fuel leads, of the parachute, the resistance of the outer shell to the heat generated, and, most important, the power generated by a known quantity of fuel.

The rocket was fired and practically all Goddard's questions were answered. It was shot up to a height of some 400 feet and the parachute opening perfectly brought it uninjured to earth and with the instruments intact.

A great step forward, this. If a projectile could be fired some hundreds of feet into the air, the principles of its design and propulsion were sound. Time only and persistent labour in its improvement were all that were necessary to produce a vessel that would travel a thousand feet—a hundred thousand feet.

People do not bestow a small fortune on a project in which they do not firmly believe, and it was but a short time after this successful test that Daniel Guggenheim placed £20,000 at the disposal of a committee of America's most eminent scientists for the development and perfection of the rocket.

The long years of patient, persistent study

and experiment had brought their reward. Dr. Goddard, we are informed by Mr. C. P. Mason, Secretary of the American Interplanetary Society, has now terminated his experiments, but the mass of his invaluable statistics will provide a firm foundation for his successor.

The German Interplanetary Society is likely, at any time, to surprise a world almost too sophisticated by scientific achievement to be surprised. Some distance outside Berlin it has set up the Raketenflugplatz, that is, the rocket-flying field. Here, on a great tract of waste land, a full-time staff of skilled engineers are working day-in, day-out, to produce a rocket that will overcome the earth's force of attraction and travel on into the ether.

The work is being carried out on proving-stands (testing-stands) on which the rockets are operated and their efficiency tested by recording instruments. To lessen the danger of dealing with such terrific explosives as the liquid fuels, each stand is equipped with a remote control by which the fuels are fed into the chamber and fired. A flight of some miles into the air is anticipated at a not too distant time.

Meanwhile Johannes Winkler, as will be recalled, in 1931 sent his rocket up 1000 feet, and its parachute brought it to earth quietly

and but a little distance from its starting point.

This height was then beaten by the Poggensee rocket with its 1500 feet and carrying among various instruments, a camera and speedometer. Again this projectile landed safely by parachute.

Amazing Speed

The speed at which the ascent is made is of the utmost importance and therefore the exultation of Reinhold Tilling may well be imagined when he sent a rocket up to nearly 6000 feet and achieved a speed of close on 700 miles an hour.

Seven hundred miles an hour is no mean speed, but the Stratospheric aeroplanes now under construction will, it is generally agreed, attain 1000 miles an hour. The rocket, however, has to travel at seven miles a *second*, or sixty times as fast as the world's swiftest aeroplane, and for this reason. The rocket will be driven by the continuously burning liquid fuels, up through the enveloping air at such a speed that it will not be overheated.

When it reaches the rarefied regions its speed will automatically increase because of the ever-decreasing resistance of the air.

By the time the rocket has reached absolutely airless space its speed should be seven miles

a second. *Should be*, for mathematicians are agreed that once a body is given this speed it will travel on for ever *without further propulsion*. That is: the force of gravity, the force of the earth's attraction, would be completely overcome.

This sets up a fascinating train of thought, does it not? If such a rocket were guided it could be made to circle the earth as many times as the pilot wished. At what speed would it continue to travel? Would that speed lessen at all? How could the pilot bring it to earth again? How——?

But we may safely leave the reader to propound all such intriguing questions and supply the correct answers.

Throughout the world, then, in this country and that, there is an ever growing company who have set their hearts on conquering space. It is a brilliant company composed of physicists, mathematicians, practical engineers, aeronauts, metallurgists, chemists, astronomers, world-famous aero-pilots. They are bringing to the prosecution of this great adventure all the accumulated knowledge of all the ages.

Into the Ether of Space

Some of these can already see the rocket with its meteorological instruments, soaring to 250

miles above the earth, and returning with their secrets. Others definitely assert that aerial travel of the future will be by rocket-driven plane in the Stratosphere and at least 1000 miles an hour. Others again stake their great reputations on the assertion that before many years, a rocket will reach the moon, if that destination be desired.

Cannot we imagine it all? The stream-lined vessel with its compact passenger-compartment oxygenated at ordinary atmospheric pressure, the cockpit of the crew, the heating apparatus, the cooling apparatus, the wireless installation, the crowded instrument board, the mass of scientific apparatus?

There is the motor—the combustion chamber—with its leads from the fuel-tanks, the cooling system, the exterior fins to give balance to the vessel and stability, the steering system, the parachutes ingeniously fixed fore and aft.

It is impossible not to indulge the fancy in the thrill of a trip moonward. The ship is rushing through the air. The earth, seen through the windows, seems to hang suspended beneath. Through breaks in the clouds the outline of the seas and continents become clear and boldly marked, in the bright sunlight.

Something is happening to the light. It is

intensely strong, and yet there is a deep blueness all around. The blueness deepens and deepens to a blackness, whilst the direct rays of the sun strike through the windows—but only on the sun side. These rays give intense heat too; yet there is an equally intense cold on the other side, the sheltered side. You see, there is no air without, and it is the air that spreads both the heat and the light of the sun. It is just like being in a pitch black room with a broad ray from a lantern cutting through the darkness. Strange effect this gleaming brightness on the sun-side, and this darkness on the other.

The earth is no longer beneath but rides alongside suspended like an immense gleaming ball. The darkness deepens. All around is a boundless world of stars, billions upon billions of them, stabbing the rich black velvet shroud of Space.

A meteor, lit by the sun, flashes perilously near. What if one of the myriad meteor-fragments for ever flying through space, pierced the craft? It would be death, for the artificially produced air of the cabin would escape.

There is no sound whatsoever from without and, even though the craft is now travelling at something near seven miles a second there is no sense of movement; there are no near-by

objects, which alone can give the sense of movement.

The earth is smaller now, the moon bigger and brighter than ever before.

One hundred thousand miles from the earth and gliding smoothly, swiftly in the mysterious airless, cloudless, soundless immensity of the universe. The Conquest of Space!

The pilot explodes a charge in a side chamber and the vessel changes direction. He decides to return to earth and fires the charge in the combustion chamber at the nose. The vessel is thus checked, its momentum is lost, and the earth immediately reasserts an effective attraction.

As the minutes pass the earth comes nearer. It is useless to attempt yet to use a parachute—it would not operate for there is no air to fill it out. The earth is coming closer; soon the outer reaches of the atmosphere will be attained. Two hundred and fifty miles only above the earth, now 200, now 150 miles. But the first parachute has already been opened and has filled out. The descent is slower. Soon, a second parachute is operated. It spreads swiftly and further checks the speed. There is a slow drifting down, the green fields come slowly up. In one minute the moon-vessel will be lying safely upon the familiar earth.

The dangers and difficulties of this great enterprise are immense; death has already come to more than one pioneer, and will completely defeat many more, but once Man has set his hand to a task, who shall say he will not triumph?

Our ancestors, returned to life, would find a world of well-nigh frightening magic—the steam-engine, the motor, the gramophone, the telephone, the telegraph, and wireless. This age has annihilated distance, and given a new interpretation to speed.

What is there left? What will our children see?

Is this—the Space Ship—one of the many marvellous things that they will see? *We* believe it is. But what do you believe?

If you think that man will achieve this magnificent adventure you will be in most excellent company. You will range yourself with such brilliant men as Professor Millikan, of cosmic ray fame, Colonel Lindberg, Esnault-Pelterie, that great astronomer Dr. Abbot, and Professor Oberth, to mention but a few.

But, success or failure, there is one thing we may all agree upon—the ingenuity of man, and his indomitable spirit.